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Optimization of dietary protein to energy level for commercial emu (*Dromaius novaehollandiae)* production to maximize fat yield

By

Prudence Motlagomang Matlhoko

Submitted in partial fulfilment of the requirement for the degree
Magister Scientiae

Supervisor: Dr. J.P. Chamunorwa (Department of Anatomy and Physiology, Faculty of Veterinary Science)
Co-supervisor: Prof. E.C. Webb (Department of Animal and Wildlife Science, Faculty of Natural and Agricultural Sciences)

September 2009

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Acknowledgments

I would like to thank:

Dr Joseph Chamunorwa, my supervisor, for giving me the opportunity to work on this project under his guidance and support.

Professor Edward Webb, my co-supervisor, for his support and guidance.

The late Professor Johnny Van der Walt, who initiated the project and made my whole MSc possible by admitting me into the Department of Anatomy and Physiology.

Mr Peter Duncan, on whose farm, the project was carried out.

Mr Mechack Ndlovu, for his support and encouragement.

Mr Kosher Ndlovu, for giving much knowledge about emus, as well as showing interest in the project.

Other staff members at African Emu Ranch, for their help in the building of camps, weighing of the birds, feeding and monitoring of the birds from the beginning to the end of the project. They provided the needed support and made sure the project run very smoothly.

Mrs. Elise Ferreira and other staff members of the Nutrilab, Department of Animal and Wildlife Sciences, for the analysis of the samples.

Hettie Rossouw and Nettie Engelbrecht, Senior technicians, at the Department of Anatomy and Physiology, Physiology Laboratory, for helping me with analysis of the samples.

Mr Michael Antwi, for being my source of strength, a friend, being, giving me support, and helping me through the hard times throughout my studies.

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Department of Agriculture, South African Emu Association, and the Department of Anatomy and Physiology for providing funding for the project.

Family and friends, for the love and support they gave me throughout these years of study.

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Declaration

I, M.P. Matlhoko, do hereby declare that the research in this dissertation, was executed by myself, and apart from the guidance from my Supervisors, I have received no assistance.

This dissertation is presented in partial fulfillment of the requirements for the degree MSc in Anatomy and Physiology.

Signed : …….

Date : …….

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List of key terms

Emu (*Dromaius Novaehollandie)*

Energy

Emu oil production

Feeding

Feeds

Nutritional requirements

Optimization

Protein treatments

Fat yield

Ratites

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ABSTRACT

This research was conducted to study the optimum dietary protein and energy ratio of finishing diets to sub-adult emu birds for greater fat accretion. The research was done at African Emu Ranch in Muldersdrift, Gauteng. Twenty-six, four to five months old emu birds were reared to an average target weight of 30.72kg on a control diet containing 17% crude protein (CP). The birds were weighed fortnightly before and during the feeding trial. Dietary treatments, containing 14% and 20% CP were specially mixed by Rustia Feeds Company and proximate analysis was done to confirm the proximate composition. Crude protein (CP), nitrogen free extract (NFE) and ether extract (EE) % were determined and metabolizable energy (ME) of feed was calculated.

The birds were randomly allocated into three groups of eight, and further assigned to two treatments and the control. Water and feed were given *ad libitum.* The feeding trial spanned eight weeks. The birds were slaughtered, and fat yield, gastrointestinal segments measurements, volatile fatty acid production and carcass weight were recorded. The fat was analyzed for lipid content and composition in terms of mono-, poly-unsaturated and saturated fatty acids.

Repeated measures of ANOVA on the pre-trial growth levels as well as pre-trial average daily weight gain of the birds showed no significant differences between the groups ($F=0.198$, $p=0.662$). The growth rate and the average weight gain of the birds during the feeding trial under the respective treatments were analyzed but the results showed no statistically significant differences (i.e. no difference between subject factors' effects ($F=0.118$, $p=0.890$). The standard variations were minimal.

The average dressed out carcass weights for 14, 17 and 20 % CP groups were 16.75, 18.65 and 19.11 kg respectively. The results of the statistical analysis of the dressed out carcass weight showed that there was a significant difference between the respective groups ($F=4.493$, $p=0.028$). The percent dressed out carcass weight (or dressing percentage) between the groups also showed a significant difference ($F=4.248$, $p=0.03$). This implies that if the objective of an emu farmer is carcass production and depending on the cost of the protein, then a 20% CP diet

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could be fed. The variations in the standard deviations were not wide. Analysis of the results of the respective digestive segments “with and without” contents, as well as their lengths showed that there were no significant differences between the groups in terms of weight.

Analysis of the volatile fatty acid (VFA) concentrations in the different intestinal segments showed no significant differences due to dietary treatments. The most abundant VFA collected from the distal and the proximal intestines was acetic acid (between 68 and 79.43 mmol). The highest concentration of acetic acid (79.43 mmol) was found in the distal ileum. The smallest volume was that of iso-butyric acid in the distal ileum.

Total average fat yield (Subcutaneous fat + Skin fat + Omental fat) for the groups was 4.1, 4.2 and 4.4 kg respectively. There was no statistically significant difference in the average fat yield per group. It can therefore be concluded that, for economical production of emu oil, the birds should be finished on diets with low protein (in this case 14% CP) to energy ratio.

The results of the analysis of the fat in respect of long chain fatty acids showed that there were no significant differences between the groups or treatments for all the different long-chain fatty acids. The results of the analysis of saturated fatty acids (27.74%), monounsaturated fatty acids (51.80%), and polyunsaturated fatty acids (20.45%) indicated that there were no significant differences between the treatment groups. The results of the analysis of lipid content indicated that the effect of anatomical location on the lipid content tended towards significance ($p=0.064$). The total mean lipid content in the omental and subcutaneous locations were 82% and 92.5% respectively. However the treatment and location/treatment effects were found to be insignificant ($p=0.29$ and $p=0.719$). The overall lipid content of the fat averaged 87.4%.

It may be concluded that, considering the cost of protein, if the farmer’s objective is carcass production, then the birds could be finished on diets with a high protein to energy ratio. However, if the farmer’s objective is emu oil production, then diets with a low protein to energy ratio should be fed.

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CHAPTER 1

INTRODUCTION

With the growing concern about dependence on pills and conventional drugs, more people are turning to natural medicines to take care of themselves. Oils derived from the emu have become popular worldwide due to their fatty acid composition; in particular the high oleic acid content that makes it very compatible with human skin oils (Emu supply feed company, 2007). The omega fatty acids are very good for alleviating high blood pressure and joint degenerative conditions. The oil penetrates the skin to soothe muscle aches, keep the joint warm without over-heating, prevents formation of scar tissue, and also used for the treatment of eczema. Emu oil provides an excellent alternative to mineral oil as lubricating base for topical and pharmaceutical preparations. The typical price is as much as $20.00 per ounce or per 50 millilitres (Jefferey, 2001).

Commercial emu farming to produce emu meat, leather and oil started in Western Australia in 1987 and the first slaughtering occurred in 1990. In 1994 all Australian states permitted emu farming and the industry produced an estimated 75,000 chicks in 1994 and 11,000 in 1995. The United States of America has the biggest population of emus, currently at 1.5 million birds. Europe, Canada and China have 15-20 000 birds each; New Zealand 2000-3000 birds and farms are being established in a number of Asian countries (Jefferey, 2001). Production technology is well developed in the aforementioned countries.

From the above, the growing medicinal, financial and economic importance of emu oil is apparent. Many American and Australian farmers are at an advanced stage of commercial emu oil production (Jefferey, 2001).

South African farmers have now joined this potentially lucrative enterprise. Still in its infancy, it is beset with the problems of pioneering and venturing into new territories when compared to the Ostrich industry. For example, the feeds have been adapted from the ostrich industry and other countries where emu farming has

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been established. The adapted feeds may not necessarily be the appropriate feeds for the emus due to climatic, environmental and other differences. Establishing this would require more detailed nutritional studies to come up with a specific diet (Jefferey, 2001). The thrust of this investigation was not to establish an emu diet but to establish the diet with the optimal ratio of protein to energy level that would result in greater fat accretion without compromising on quality.

Anatomically, the capacity of the emu's digestive tract to handle fiber is, much smaller than that of the ostrich. While the ostrich has some ten meters of colon, the emu has virtually no colon. This anatomical difference would suggest that the nutritional requirements of emus would differ from that of ostriches (Mannion 1995).

1.1 IMPORTANCE OF THE STUDY

Commercial emu farming has only recently been introduced into South Africa. Currently, and in the foreseeable future, the oil component obtained from this bird will far outweigh the meat and skin components in terms of income for the farmer. Thus maximizing the production (quantity) of fat, while maintaining the quality of the oil produced, would benefit the farmer and therefore the industry as a whole. Future growth of such an industry will result in job creation and the improvement of the local communities where farmers are located. The possibility of future export of emu oil is a real prospect. Determining the optimal diet to achieve these benefits would be of great economic importance to the individual farmers, local communities and the country as a whole.

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1.2 OBJECTIVES OF THE STUDY

The main objectives of this study were therefore:

1. To optimize protein to energy levels (ratio) in commercial emu production to maximize fat yield.
2. To determine the effect and interaction of two different levels of protein and more or less constant energy level on fat deposition.

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CHAPTER 2

LITERATURE REVIEW

2.1 The Ratite family

The emu (*Dromaius novaehollandiae*), ostrich *(Struthio camelus*), cassowary *(Casuarius)*, kiwi *(Apteryx australis*), and rhea *(Rhea americana)* form the ratite family of flightless birds. Ostriches, rheas, and emus are the ratites that are mainly raised as alternative livestock in the United States (Mannion 1995). Male ratites have elongated necks and relatively long, heavily muscled legs adapted for running. Even the diminutive kiwi can scurry through the undergrowth with amazing speed. All ratites use their limbs in both defense and offense by thrusting forward (Fowler 1991). The Ostrich and Cassowary are capable of disemboweling a person with one slashing blow, thus one should be very careful when working with these birds.

Of all the ratite species, Ostriches *(Struthio camelus*) have been farmed for the longest period. Initially, they were farmed in South Africa for their plumes, which were in great demand in the late 1800's for the adornment of women garments e.g. hats and hand bags. Ostriches are now raised mainly for their attractive, durable leather and low-fat red meat. Ostrich leather has a distinctive quill marking and is suitable for making boots, briefcases, footwear and many other accessories (Mannion *et. al.,* 1995). Rheas are farmed in South America and the United States of America. The main products of rheas are similar to those of Ostriches, being leather and meat (Mannion *et al.,* 1995).

Emus are indigenous to Australia, where the aborigine people use emu oil as medicine for almost all their ailments. These birds are now farmed commercially in Australia, Canada, Europe and the USA (Whitehouse *et. al*., 1998). Emus are raised for their oil (fat), meat and skin (Whitehouse *et. al*., 1998; Frapple, O' Malley, Snowden and Hagan, 1997). About 4-5 years ago, emus were introduced in South Africa as a new farming enterprise.

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Although these birds have some similarities in appearance, there are distinct differences between the species in their anatomy and origin.

2.1.1 General anatomy and behavior of the emu

Jefferey (2001), states that the name emu comes from the shape of the keel or breastbone, which resembles a raft and is actually a large, mostly cartilaginous plate. Emus have poorly developed wings, are flightless and have three toes (the ostrich has two). From hatch to about 2 months of age, the chicks have longitudinal stripes. From 3 months to about 1 year of age they have a dark brown neck and head, with beige and brown body feathers. Mature birds have a bare blue neck, which begins as a crescent behind the eye, black feathers on the head and mottled body feathers. The feathers of the male and female emu look alike. The female generally is the larger of the two, especially during the breeding season when the male may fast. The female is the dominant member of the pair. She chooses a mate and selects and defends a territory for the nest. The male emu sits on the nest. Emus live for about 30 years and may produce eggs for more than 16 years. An adult emu stands about five feet (1.5 m) tall, weighs about 120 to 150 pounds (54-68 kg), and can run as fast as 30 miles (48 km) per hour. They are not easy to catch if they get loose! Emus use their long legs for swimming and defense as well. When observing adult female emus, one can hear an unusual, deep booming sound, like that of a bass drum, coming from a wind sack in the front. It is heard more frequently when they are excited or upset. The males don't seem to have a wind sack like the females, but the males make a grunting and groaning sound, which is less audible than the booming of the females. Both male and female emus have a third eyelid, a white membrane that darts from front to back, which engages briefly during pecking or defense (Jefferey 2001).

Unlike the ostrich and rhea, emus have a gentler disposition. They can also be quite comical in their antics - such as watch pecking (they are attracted to shiny things), and hat stealing. Emu feathers are long and thin on the body with beige feathers

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interspersed with black ones. On the surface, the mop-like feathers appear oily; under the surface, they are dry and soft. On their long necks, the emus' feathers are downy and short (Jefferey 2001).

2.2 Management and housing of ratites

Managing a farm efficiently means keeping overhead costs as low as possible while keeping productivity as high as possible. The general health and well being of the birds are of utmost importance. Unhealthy birds are poor producers, are unmarketable, and a drain on financial resources.

2.2.1 Housing

All ratites live long, especially in captivity. In the farming of ratite species, many of the basic requirements are similar: high mesh-type fencing, incubating equipment, breeder pens/camps and sheltered chick rearing facilities. Ratites adapt to most climates, so long as they are given proper protection and management (Mannion *et al.,* 1995). Jefferey 2001 indicates that the pen size for an adult emu pair should be about ⅛ to ¼ acre. Five-foot fencing is adequate for adult emu, but some sources recommend five and a half foot to 6-foot fence with a top rail. Alleys between pens (with gates opening into alleys) make it easier to move birds. Exercise pens and large pens for groups of birds usually are long and narrow rather than square to provide more running room. The facility should include an isolation or quarantine area for sick or new birds as far as possible from the remainder of the flock.

2.2.2 Chick rearing

Newly hatched chicks cannot regulate their body heat and need a source of warmth until 3 months old if the outside temperature is cold. Maintain temperature at 32-35^{o}C for the first 3 days after hatch. Decrease temperature by 5 degrees every 2 weeks. In warm weather, use supplemental heat only at night. The heat source should be of adequate size for all chicks to get around it, and the pen area should be large enough so that the chicks can get away from the heat to avoid overheating.

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Brooder boxes for chicks 1 to 3 days old are typically about 1 foot high and 2 x 3 or 3 x 4 feet in area per 10 chicks. Chicks may pile and smother one another. Avoid overcrowding, extremes of heat or cold and sudden fright. Piling generally becomes less of a problem after the first few weeks. The floor of the brooding area must be easy to clean and have good traction. Chicks can be moved to an 8 x 8-foot nursery pen at approximately 21-29^{o}C on day four and then into progressively larger pens. Encourage outside exercise periods and sunbathing starting at 5 to 7 days of age, depending on the weather.

2.2.3 Breeding pairs

2.2.3.1 Pairing

Separate juvenile groups by age and/or size into large communal pens (50 x 100 feet) or pastures. Grass usually survives well in emu pens except along the fence, where the birds' tendencies to fence walk kills it. Breeding pairs select their mates in large communal pens. The female emu chooses the male and will become quite aggressive toward males she doesn't find suitable. In pens where adults are pairing up, some producers leave the corners loose to provide an escape route for birds being chased off by jealous rivals or angry females. These birds escape through the corner into an alley between the pens. Sometimes aggressive females are penned separately from the males, but with a common fence. Usually birds that settle down together in the evening will successfully pair up.

2.3.2.2 Shelter

Individual pens and shelters are provided for breeding pairs; however, polygamous arrangements have been successful. Shelters may be made of wood, tin, fiberglass or other materials. Fiberglass is lightweight and easy to move (if self-contained). Fiberglass shelters are quite bright inside because of penetrating sunlight. Shelters with good lighting appear to encourage the emus to nest inside (Jefferey 2001). Bedding, such as straw inside the huts, encourages egg laying and makes collection of clean egg possible. Adult emus appear to be quite tolerant to cold weather.

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Normal reproduction (more than 30 eggs per pair) has been reported in North Dakota in barns "heated" to 2-4^{o}C with an outside temperature of 10 ^{o}C(Jefferey 2001).

2.2.4 Transportation

Emus can be moved for long distances without being hurt (Jefferey 2001). Most of the time, transporting them does not harm their production levels once they get used to their new environment. However, there have been instances when a hen may not lay eggs again after being transported (Jefferey 2001).

2.3 Anatomy of the digestive system of ratites

The anatomy and functions of the digestive tract of the ratites have been well documented (Fowler 1991; Herd & Dawson 1984; Mannion 1995; Skadhauge *et al.* 1984;Swart, Mackie, & Hayes 1993). These birds differ from poultry in that they do not possess a crop. One would also expect emu nutrition to differ from that of the ostrich because of important anatomical differences in their respective digestive tracts (Fowler 1991). For example, feed stays in the gastrointestinal tract of the ostrich for 24-36 hours while the transit time in the emu is only 6-8 hours (Holle 1997). Emus, therefore, need a diet that is specially formulated for them. Animal feeds are formulated to meet the requirements of the animal in question under defined conditions and any subtle differences in these conditions should be carefully considered. Most ranchers have found that patillized feeds called “ratite feed” make the best formulas for ratites (Holle 1997). The formulation of a balanced diet is fundamental to the commercial production of emu, and this process depends on the knowledge of the digestive system and nutrition of the bird, as well as the purpose for which the bird will be used e.g. as breeder bird or production (slaughter) bird.

The inner lining of the esophagus is deeply furrowed thereby allowing considerable expansion for the ingestion of bulky feed. The proventriculus is quite distensible and may serve as a feed storage organ. The total length of the alimentary tract in

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the emu is extremely short relative to the ostrich and domestic fowl. While the length of the small intestine of the emu and ostrich, in proportion to live weight, is comparable it is relatively much shorter than that of the domestic fowl. The ostrich has a well-developed colon and spiraled caecum which is thought to play an important role in the production and absorption of volatile fatty acids (VFA) and other metabolites produced by microbial fermentation of cellulose and hemi-cellulose (Holle 1997). On the other hand the emu has a very short colon and unlike the ostrich, very little microbial fermentation can take place in the colon.

The total length of the digestive tract of the emu relative to its live weight is approximately ten times less than that for the domestic fowl. The time taken for food to pass through the digestive tract is variable, depending in part on the nature of the item ingested. For example, plant particulate matter will take an average of five to six hours, whereas intact wheat grains may take from one to two days. It would be expected that large particles of insoluble grit would be retained for a period in the gizzard for it to be effective in aiding the physical maceration of feed (Mannion *et al.,* 1995). Table 2.1 shows the different parts of the digestive system of ostrich, emu and the domestic fowl.

Table 2.1: Comparison between the digestive tracts of emu, ostrich and domestic fowl (Herd & Dawson 1984)

Region	**Length (mm/kg LW)**			**Relative Length %of total**		
	Emu	Ostrich	Fowl	Emu	Ostrich	Fowl
Proventriculus	3.6	4.3	7.4	3.7	1.3	8.7
Gizzard	2.9	2.5		3.0	0.8	
Duodenum	13.1	61.9	120	13.4	18.4	15.4
Jejunum	32.1		416	32.8		53.3
Ileum	37.1	54.8	64	37.9	16.3	8.2
Caeca (Paired)	1.6	26.2	68	1.6	8.3	8.7
Colon	7.6	184.5	44	7.8	54.9	5.6

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2.4 Digestion

Ostriches are hindgut fermenters therefore similar to the horse. If a horse is fed a corn diet, which is low in fiber, about 75 percent of the soluble carbohydrate will be digested and absorbed in the small intestine (Melvin 1993). Conversely, with a high- fibre diet such as an alfalfa-beet pulp mixture, only about 40 percent of the soluble carbohydrate will be digested in the small intestine. Thus the fibre content may protect the soluble material to some extent from release and enzymatic hydrolysis. In addition, fibrous material is moved through the intestine faster because of the stimulation of motility due to its bulk. Scheideler & Angel (1994) measured volatile fatty acid (VFA) production in the ostrich proventiculus. The VFA produced in large amounts was acetate, which was suggestive of foregut fermentation. Ostrich may be able to extract more dietary energy from high fibre seeds, such as alfalfa and hay, than can other types of poultry. However, the nutritional significance of this fermentation has not been quantified (Scheideler & Angel 1994). The addition of insoluble grit or small pebbles to the feed of adult ostriches may increase the digestibility of the fibre fraction.

Herd & Dawson (1984) showed that emus were able to digest 35-45 % of the neutral detergent fibre (NDF) of an unspecified diet i.e. 50-60% of the hemi cellulose and up to 20% of the dietary cellulose and lignin. This is in spite of the relatively simple gut and rapid passage time of plant particulate matter (5.5 hours) of the liquid phase. The principal site of digestion was the distal small intestine or ileum and while they did not conclusively prove utilization of the derived energy, they concluded that up to 63% of the standard metabolism and 50% of the maintenance requirement for energy could be provided by digestion of 36% NDF in the highest fiber diet.

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2.5 Nutrient requirements of emus

Angel (1996c) indicated that scientific information available on the energy and protein requirements of emus was published following studies on a limited number of adult birds in Australia. Four adult emus ranging in weight between 28 kg and 48 kg had a maintenance energy requirement of 67.9 cal ME/kg.75 (body weight)/day. The maintenance nitrogen requirement for these birds was found to be 0.09 g/kg.75 (body weight)/day or 0.56 g protein/kg.75 (body weight)/day. This means that a 45.5 kg (l00 lb) emu would require 1. 303 kcal of metabolizable energy/day and 10.9g of protein/day for maintenance. The apparent nitrogen requirement is low compared with other avian species. This may be partly attributable to the contribution of microbial nitrogen being ignored in measuring fecal nitrogen in the balance study. The lysine requirements of starting emus have been found to be 0.86% of the diet. This value is based on trials in which birds were fed diets with a lysine content ranging from 0.575% to 1.15%. Unsexed emus from 23 to 65 days of age were fed isocaloric (2.748 kcal, metabolizable energy/kg) but not isonitrogenous diets (Scheideler & Sell 1996).

Minaar (1998) also notes that the nutritional requirements of emu have not been sufficiently researched. However, many feed manufacturers have taken it upon themselves to conduct research on emu nutrition. Feed must contain the proper balance of carbohydrates, proteins, fats, fiber, vitamins and minerals to meet the needs of a particular animal at a given stage of growth or of production. In general, carbohydrates and fats provide energy (metabolizable energy); proteins are needed for tissue growth and repair; fibre is needed for normal bowel function and may be used as a source of energy by adult birds, whose intestines contain the beneficial bacteria necessary for fermentative digestion of fibre (Minaar 1998).All ratites need variety in their diets, not just grass, and are probably better classified as “browsers” than grazers, as far as the vegetative portion of their diet is concerned. In the wild, ratites eat seeds, and herbaceous plants (Mannion *et al.*, 1995).

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Commercial rations for ratites are available from a number of sources (Jefferey 2001). Most commercial feed companies are producing starter, grower and breeder rations in mash or pellet form. The manufacturers may recommend limits on the addition of other sources of roughage or nutrients, such as alfalfa hay. Protein contents vary from 16 to 22 percent. Nutritional requirements of the emu have not been determined by scientific research; however, similarities of the emu and chicken digestive systems suggest that their nutritional requirements may be similar. Many farmers feed newly hatched chicks a mixture of chopped greens, a commercial starter crumble and a vitamin/mineral supplement. The greens are thought to attract the birds to the feeder and stimulate feed consumption; the nutritional benefits are negligible. Water may be offered before food by about 12 hours. Grit is offered with the food although it is not necessary if feeding a processed commercial diet. Chicks are usually fed twice a day for about an hour. Diets are usually in a small pellet or large crumble form for chicks. Fiber content varies between 7 and 15 percent. Some nutritionists recommend fiber content between 5 and 10 percent or diets with more.

Specialty feeds (2005) are of the view that to formulate diets for growing emu it is necessary to compromise between reducing the cost of the diet with optimizing the nutritional parameters that we know or think are important, but stress that the important nutritional parameters should not be compromised. In addition to amino acid, vitamins, minerals, essential lipid and energy requirements, the issue of diet palatability should be taken into account with grower formulations. Specialty feeds (2005) recommends the following nutritional parameters for emus: Protein 16%, Fat 6.6%, Crude Fibre 10.4% and 11MJ/Kg of ME.

Blake & Hess (2004) analyzed the effect of protein on growth and carcass yield of emu using 14%, 16% and 18% levels of protein and fixed level of energy. The results indicated that emu fed a low protein diet exhibit the ability to compensate for growth and carcass yield. Seventy-two Emu of mixed sex (mean age 107 days) were randomly distributed among six pens (4.2 x 24.2) with 12 birds/pen. Two

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pens each were fed a 14, 16 or 18% protein (2860 kcal/kg) corn soybean meal diet from 0-176 d on test. From 176 – 248 d on test, a 14% protein finisher diet containing either 2860kcal/kg or 3080 kcal/kg was fed to each of two pens fed the same protein level prior to day 176. Body weights were obtained at 0, 15, 79, 108, 135, 176 and 248 d on test for each bird, while *ad libitum* feed consumption was measured for each pen. At 273 d, five birds were selected for slaughter from each pen based on mean body weight and carcass, fat, neck, bone, fan and fillet muscle measured. Body weight gain was less ($P<0.01$) in birds fed the 14% protein diet during the 176-day experimental period and was not affected by energy level during the finishing period. Cumulative feed efficiency (kg feed/kg gain) for the 248 d period for birds fed 14, 16 or 18% protein was 12.08, 11.05 and 10.92 respectively ($P>0.05$). Carcass weights and yields were unaffected by treatment. Carcass weights for females were greater ($P>0.05$) than for males (23.17 vs. 21.57 kg). Average amounts of fat, bone, neck, fan and fillet muscles, second muscles and ground meat as a percentage of carcass yield remained unaffected by treatment ($P>0.05$) (although values for females were numerically greater than for males) and averaged 18.9, 18,2, 3.8, 8,6 and 27.5% respectively. Results indicated that emu fed a low protein diet exhibit the ability to compensate for growth and carcass yield.

2.5.1 Vitamins

They are present in the diet although some vitamins may be obtained by coprophagy or be synthesized by micro-organisms in the intestinal tract.

2.5.2 Minerals

Minerals are essential for normal growth, development and health. They must be present in the diet either in relatively small amounts, for example calcium, phosphorus, manganese, sodium and chloride or only trace amounts, for example potassium, iron, copper, iodine, zinc, selenium. Deficiency may result in diseases. For example, the development of leg deformities has been cited as a common problem in captive bred emus, which may be linked to calcium/phosphorus

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imbalance and methionine deficiency. Maternal malnutrition has also been implicated. Frapple (1997) observed that restricting the time of access to mixed feed to a period of only four hours each day from about 10 to 30 days of age will minimize the incidence of leg disorders in emu chicks. Interestingly, feed restriction has similarly been found effective in reducing these disorders in broilers. However, the incidence of leg deformities has not decreased in the past 40 years despite an intensive research effort in this area in birds.

2.5.3 Fibre

Emus can digest only about 20 percent of the cellulose and lignin in their diet. It has been estimated that the energy derived from this can satisfy about 11 percent of their energy requirement for maintenance (Frapple 1997). Their limited capacity to digest fibre is consistent with the observation that, in the wild, emus eat large insects, small vertebrates and those parts of plants in which nutrients are concentrated such as growing shoots, flowers, fruits and seeds (Frapple 1997). It also suggests that immature, rapidly growing emus should be fed diets relatively low in fibre and similar in nature to conventional poultry grower diets. Some fibre is necessary to promote healthy gut function but in nutritional terms its value is low.

2.5.4 Proteins and amino Acids

Feed protein is broken down in the stomach and intestines into its constituent amino acids, di-peptides and tri-peptides, which are then absorbed into the blood and used for growth and repair. Thus the Emu's requirement for protein is in effect a requirement for amino acids and therefore, it is the amino acid composition of the feed that is the crucial factor.

According to Angel (1996b), the term "proteins" designates the crude protein content of feedstuffs and diets. Crude protein is defined as the nitrogen content multiplied by the factor 6.25, assuming that the nitrogen content of proteins averages 16% by weight. Proteins are composed of long chains of amino acids

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linked together. The physical and chemical properties of proteins vary greatly, depending on the total number and linkage sequences of amino acids as well as the proportion of the different amino acids in the protein.

The dietary crude protein specification reflects the requirements for amino acids. Amino acids are components of all tissues, including muscle, bone, skin, feathers and eggs. Amino acids also are required for synthesis of biologically active substances including hormones and enzymes, for transport of nutrients in the body and to maintain ionic balance of body fluids. A deficiency in dietary protein or amino acids results in reduced growth in young animals and decreased reproductive performance of mature animals, impaired feed efficiency, poor feather development, lethargy and reduced resistance to disease (Angel 1996a).

Proteins of body tissue contain as many as 22 amino acids. Eleven of these amino acids must be supplied in the dietary protein as amino acid supplements for chickens and turkeys because they cannot synthesize these amino acids at rates sufficient for maintenance and growth. These 11 amino acids, termed essential amino acids, are:
Arginine, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. A part of the dietary requirements for glycine, methionine, and phenylalanine can be satisfied by serine, cystine, and tyrosine respectively. Chickens and turkeys do not need dietary glycine after 3 to 4 weeks of age. Little information is available on the essential amino acid requirements of ratites. A commonality exists among a large number of animals with respect to essential amino acids, although absolute requirements for each amino acid differ among species. South African researchers use data on amino composition of 7-month-old ostriches and feed consumption during different age intervals from hatch to maturity, to estimate essential amino acid requirements of ostriches (Angel 1996d). In the absence of information on essential amino acid requirements of emu and rheas, values used for broiler chickens are assumed to reflect the needs of these ratites. Amino acid requirements of young poultry are relatively high during early

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growth (Merck Veterinary Manual, 2003, Appendix 1). As birds grow toward physical maturity, dietary amino acid requirements decrease because of changes in growth rate and metabolic needs in relation to feed intake (Angel 1996a).

A blend of dietary protein sources and supplemental methionine and lysine can be used to formulate diets to meet essential amino acids requirements. Sufficient protein should be included in the diet to satisfy most of the metabolic needs for nonessential amino acids, which otherwise would have to be synthesized from essential amino acids. In practical terms, diets are formulated to meet essential amino acids and protein requirements in the most economical way. The principal sources of dietary protein are cereal grains, (corn, barley, sorghum, wheat and oats), alfalfa meal, and ingredients with relatively high protein content (soybean meal, animal by-product meals, and fermentation by-products). Appropriate blending of these ingredients, within the constraints of economic and dietary considerations, result in formulas that fulfill essential amino acid requirements. Frequently, mixtures of protein sources will not supply sufficient methionine and/or lysine, and supplemental amino acid sources are needed to balance the diet. Supplemental sources of these amino acids are available commercially and are well utilized by avian species (Scheideler & Angel 1994).

The feeding quality of protein-contributing ingredients depends on amino acid composition and digestibility. Protein sources vary in digestibility, which influences amino acid availability. Protein sources derived, in part, from animal tissues, such as feathers or hooves, are generally less digestible than proteins derived from most plant sources. Improper processing involving either under or overheating of any major protein source, including soybean meal, corn gluten meal, meat and bone meal, or blood meal, will reduce protein digestibility and the availability of amino acids. Feeds are usually formulated to contain predetermined protein and amino acid levels. Any factor that affects intake will influence the quantity of protein and the amino acids consumed. Major factors influencing feed intake include ambient temperature, dietary energy content, and physical texture of

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the diet, accessibility to feed, and health status. To maintain adequate, but not excessive, protein and amino acid intake, adjustments may be required in protein and amino acid percentage of the diet to compensate for changes in feed intake.

According to (Fowler 1991), the ability to supply the nutritional requirements of emus depends on the feed composition, that is, the concentrations of the essential nutrients in the feed and the amount of feed consumed by the birds. When all of the emus' diet comprises a compounded feed, quite precise control can be exercised over their intake of nutrients. When a proportion of their diet is derived from browsing, their quantitative intake of available nutrients is less predictable. For rapidly growing emus destined for slaughter it seems logical to reduce the dependence on range and instead supply compounded diets formulated to least cost specifications. An examination of the growth curve of emus suggests that a three-phase system of feeding may be appropriate. Phase one could be known as a starter phase and would cover the period from hatching to when the emus attain an average live weight of approximately 10 kg (14 weeks of age). Phase two, a grower phase, would cover the period from 10 kg live weight to 25 kg live weight (34 weeks of age). Phase three, a finisher phase, would be that period from 25 kg live weight through to slaughter. The purpose of dividing the growing period into phases is simply to signify periods in which the emu requires a change in its dietary nutrient composition to best meet its current level of production. However, until the appropriate nutrient response data are known, the suggestion of a three phase system remains only tentative.

At this time perhaps the best guide is a theoretical estimate of the requirements for lysine, methionine plus cystine and energy of male ostriches based on limited carcass composition data and incorporating several untested assumptions. The data have been tabulated by (McDonald 1991) and expanded by him to include calcium, phosphorus and sodium as shown in Table 2.2.

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Table 2.2: Requirements for lysine, methionine plus cystine and energy for emus at different growth stages.

	Starter	**Grower**	**Finisher**
Metabolisable energy (ME, MJ/kg)	11.2	10.2	10.2
Lysine (%)	0.9	0.8	0.7
Methionine + cystine (%)	0.7	0.7	0.6
Calcium (%)	1.6	1.6	1.6
Available phosphorus (%)	0.6	0.6	0.6
Sodium (%)	0.2	0.2	0.2

Recent Australian research (Mannion 1995) has quantified the response of young growing emus in the starter phase to diets differing in lysine content. The results show that the lysine requirement for maximum growth rate (126 g/d) is 0.81 g lysine/MJ of metabolisable energy (ME). Thus a diet containing 11.2 MJ ME/kg should contain 0.9% lysine which is in agreement with the estimate given by (McDonald 1991).

Because the growth rate and feed intake of emus will vary with changes in the energy concentration of the diet it is more appropriate to relate the requirement for lysine and other amino acids to energy content. In practice this is done by expressing the requirement for lysine as g lysine per mega joule of ME. Other amino acids are expressed as a proportion of the lysine level. These conventions have been adopted in the table of suggested nutrient requirements of growing emus. These diets should contain a comprehensive chicken grower vitamin and mineral premix (Table 2.3).

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Table 2.3: Nutrient requirements of growing emus

	Starter	**Grower**	**Finisher**
Metabolisable energy (MJ/kg)	11.2	11.0	11.0
Lysine (g/MJ)	0.80	0.75	0.70
Methionine (ratio to lysine)	0.50	0.50	0.50
Methionine + cystine (ratio to lysine)	0.80	0.80	0.80
Tryptophan (ratio to lysine)	0.19	0.19	0.19
Isoleucine (ratio to lysine)	0.65	0.65	0.65
Threonine (ratio to lysine)	0.60	0.60	0.60
Calcium (%)	1.6	1.60	1.6
Available phosphorus (%)	0.6	0.6	0.6
Sodium (%)	0.2	0.2	0.2

The energy concentration adopted for diets for growing emus is usually that which minimizes the cost of feeding per unit of end product produced. With emus having such a diversity of end products and, in the absence of specific feeding regimens tailored to specific end products, it is advised that the energy level which minimizes the cost per tone of the diet be selected having regard to meeting the amino acid specifications given earlier. Too low an energy level, however, will result in a bulky diet which may restrict feed intake particularly in young birds to levels which fail to meet the energy needs of the bird for optimum growth. In the starter phase a minimum metabolisable energy level of 11.2 MJ/kg is recommended (Mannion 1995). Example of ingredients with percentage composition for growing emus is provided in Table 2.4.

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Table 2.4: Example of diets for growing emus (percentage composition)

Ingredients	**Starter**	**Grower**	**Finisher**
Sorghum	34.7	30.9	31.6
Wheat	36.0	30.0	30.0
Meat and Bone Meal (55%)	10.3	10.0	10.1
Soya bean Meal (45%)	3.2	-	-
Sunflower Meal (32%)	9.9	8.6	6.7
Cottonseed Meal	2.9	-	-
Millrun	-	15.0	15.0
Lucerne Meal	-	2.9	4.1
Limestone	1.8	1.5	1.5
Salt	0.28	0.21	0.20
DL Methionine	0.23	0.19	0.17
L Lysine HCl	0.23	0.17	0.11
Mineral and Vitamin Premix	0.50	0.50	0.50

2.5.5 Long chain fatty acids

Fatty acids are classified according to chain length and by the number of double bonds, or points of unsaturation, in the chain. For example, palmitic acid is a fatty acid with sixteen carbons and no double bonds; thus in scientific nomenclature it is abbreviated as "16.0". Because this fatty acid contains no double bonds, it is termed a "saturated" fatty acid. Fatty acids with one double bond (one point of unsaturation) are called "monounsaturated" fatty acids, and those with two or more double bonds are called "polyunsaturated" fatty acids. Oleic acid or 18:1 is a common monounsaturated fatty acid, and linoleic acid or 18:2 is a common polyunsaturated fatty acid. Any natural fat contains a mixture of all three types of fatty acids attached to a glycerol "backbone". These compounds are called triglycerides. If a fat contains triglycerides made up of mostly saturated fatty acids, such as palmitic acid, then this fat is called a saturated fat Craig-Schmidt, *et al.*, *(*1995).

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2.5.6 Energy

Herd & Dawson (1984), states that energy represents the capacity of dietary carbohydrates, fats, and amino acids to support all life process through oxidation. Ingredients high in carbohydrates and/or fats are very good energy sources and include the cereal grains and full-fat soya-bean meal.
Metabolisable energy (ME) can be calculated using the following equation:

ME (kcal/kg) = [(3.5*CP) + (8.5*C fat) + (3.5*NFE)]*10*4.184 Where CP = crude protein, C = crude and NFE = nitrogen free extract.

According to (Angel 1996e; Scheideler & Angel 1994), terms used to describe energy in animal nutrition are based on initial measurable quantity, gross energy (GE). This is the heat of combustion or the heat released when a substance is completely oxidized (burned) to carbon dioxide and water. The gross energy of an ingredient is the maximum energy of a substance and is measured using an adiabatic bomb calorimeter. The gross energy of an ingredient depends on the proportion of the component nutrients, fat, carbohydrate and protein. The gross energy content of the major nutrient categories is carbohydrates, 3.7 (glucose), 4.2 (starch), protein, 5.6; and fat, 9.4 kcal/g. Minerals, vitamins, and water do not contribute to dietary energy. Although gross energy is the maximum energy in a substance, not all of the energy is available. Apparent digestible energy (DE) is the gross energy of a feed minus the gross energy in faeces. Most birds excrete faeces and urine together through the cloacae, making it difficult to measure digestible energy without surgical alteration of experimental subjects. Some separation of urine and faeces occur in ostriches due to the anatomy that allows voiding of urine and faeces at different times (Scheideler & Angel 1994). It is difficult to completely separate feces from urine in ratites, and thus digestible energy is not used as a basis for feed formulation for avians.

Apparent metabolizable energy (ME) is defined as the gross energy of the feed minus the gross energy of the feces, urine and gaseous products of digestion. In

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poultry, the gases produced during digestion are considered negligible. In ratites, gaseous substances, such as volatile fatty acids (VFA) and methane are produced by microbial fermentation of fibrous compounds in the lower digestive tract. In emus, this takes place in the distal ileum. The proximal large intestine and caeca are the sites of VFA production in ostriches. The large caeca and proximal large intestine are the sites of cellulolysis in rheas. The energy from products of fermentative digestion in ratites may be of importance although this has not yet been determined. Current methodology (total collection or a marker system) used to determine energy values of ingredients or diets fed to ratites has assumed that the volatile liquid components are negligible (Scheideler & Angel 1994).

The metabolizable energy of a feed can be calculated on the basis of certain assumptions. Assuming 100% digestibility of fat, protein and nitrogen-free extract, the concentration of these can be multiplied by 8.7, 4.4 and 4.0 kcal/g, respectively, resulting in an approximately metabolizable energy value for the ingredient. It is important to note that digestibility varies considerably among ingredients, and thus known digestibility values should be used to avoid errors. This system to predict metabolizable energy has limited use in poultry. The predictive value for dietary energy in ratites is even more questionable because of microbial digestion of dietary fiber. Other indirect methods for estimating metabolizable energy are available, but have limitations. Net energy (NE) is the metabolizable energy less the heat increment. Heat increments represent the heat released during digestion and fermentation of feeds, absorption of nutrients, product formation, and formation and excretion of wastes. Net energy is used for body growth, physical activity and reproduction. The efficiency with which metabolizable energy is used for maintenance, activity, growth or egg production differs; thus, there is no specific net energy value for an ingredient or feed (Scheideler & Angel 1994).

The ability of commercial poultry to ferment fiber is very limited and fiber does not contribute to the metabolizable energy value of an ingredient for chickens and turkeys. The apparent digestion of fiber (neutral detergent fiber) in chickens varies

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between 6 and 9%. In adult emus, the digestibility of neutral detergent fiber is as high as 45% and in ostriches may attain 63%. The greater capacity of the emu and ostrich to ferment fiber will have an effect on the amount of metabolizable energy these species can derive from ingredients containing varying levels of fiber. For example, the metabolizable energy of alfalfa for poultry is 1200 kcal/kg. The determined metabolizable energy of alfalfa for ostriches is 2127 kcal/kg. Poultry metabolizable energy values have been used for formulation of ratite feeds due to lack of specific metabolizable energy values for ingredients incorporated in ratite diets. When using poultry metabolizable energy values for juvenile and mature ratites, the actual energy of the diet will be underestimated, especially when the diet contains high levels of fiber. It is also important to note that the actual energy derived from an ingredient will probably differ between ostriches and emus, due to higher capacity for fiber digestion in ostriches. It is estimated that microbial degradation of dietary fiber (including cellulose and hemi-cellulose) may contribute up to 75% of the metabolizable energy requirement for maintenance in the growing ostrich (Scheideler & Angel 1994).

According to (Angel 1996f), studies in South Africa has determined the true metabolizable energy (TME) for local feedstuffs. Assuming that a diet is adequate in essential nutrients, commercial poultry consume feed to meet energy requirements. The ratio of energy to other essential nutrients is the basis for formulation of diets for chickens and turkeys. This approach should be used with caution in ratites, and the obvious limitations regarding cellulose digestion should be considered. Deficiencies or excesses of essential nutrients can influence feed consumption, affecting their relationship of energy to essential nutrients. If a diet has a gross excess of a specific nutrient, feed consumption may decrease in proportion to the potential deleterious or toxic effect of the nutrient. Similarly, a nutrient deficiency may lead to an increase or a decrease in feed consumption, depending on the nutrient and the severity of the deficiency. The relationship between energy and feed consumption in immature ratites is assumed to be similar to that of poultry, but this has not been proven. Observations based on free choice

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diets in ostriches, emus and rheas have shown preference based on energy intake in the absence of obvious deficiencies or excesses of nutrients. This implies that high-energy diets will be selected in preference to formulations with lower metabolizable energy values, but data is not available on potential intake changes (Scheideler & Angel 1994).

2.6 Water

An adequate supply of water of acceptable quality is essential for the health and well being of ratites. Water is the nutrient required in greater amounts and a restriction of water intake results in a marked reduction in growth, poor feed efficiency, and impaired production. Poultry are adversely affected by as little as 12 hours of water deprivation. Ostriches, 4 to 6 months old, deprived of water for 24 hours reduced feed intake by 45%. A further decline of 67% was observed during 24 to 48 hours of water deprivation, and body weight decreased 31% by the end of 48 hours (Scheideler & Angel 1994).

The importance of water is indicated by its prevalence in the body. Water constitutes 50 to 85% of body weight, depending on age and body condition of animals, and is a major component of every cell of the body. Water possesses many chemical and physical properties that make it a very effective participant in and facilitator of virtually all body processes (Scheideler & Angel 1994).

2.7 Practical aspects of emu and ostrich nutrition

According to (Scheideler & Angel 1994), emu diets must be formulated with regard to the high variation in feed consumption, depending on season, climatic conditions, age, and breeding status. Adult birds will decrease feed consumption by 50 to 75% during the breeding cycle. The reduction in intake is more pronounced in the male than the female. As soon as the breeding season is over, emus tend to over consume feed for 10 to 20 days before resuming customary intake of 0.9 to 1.8 kg/day (2 to 4 lbs/day). Variation in feed consumed is also

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noted in growing birds, which show a plateau during the late summer and fall and an increase during winter and spring. Future trends in commercial production will influence dietary specifications.

Precise nutrient requirement or recommendation levels are not available for ratites as in commercial poultry. Nutritionists associated with the major feed manufacturers are aware of the quality and composition of ingredients and can draw from a wide range of available products to formulate balanced diets. Small-scale producers should be dissuaded from mixing their own feeds. Purchase of commercial diets from a reputable supplier will generally provide an adequate intake of nutrients, approximating the requirements of the age and breeding status of the flock or individual ratite species(Scheideler & Angel 1994).

2.8 Effects of varying dietary protein on growth, nutrient utilization and fat yield: findings from studies in animal science on cattle and chickens.

Blome *et al.* 2003, studied growth, nutrient utilization, and body composition of dairy calves fed milk replacers containing different amount of protein. The objective of the study was to quantify the relationships between protein contents of milk replacers and growth, body composition, and nutrient utilization in pre-ruminant Holstein calves. Male Holstein calves <1 week of age were allowed a 2-week adaptation period after purchase, and then were blocked by BW and assigned randomly within block to either a baseline slaughter group or one of four experimental groups (n=8 to 9 per group). Treatments were iso-caloric milk replacers (12.5% solids) fed at 12% BW that contained 16.1, 18.5, 22.9, or 25.8% CP (DM basis) from Whey protein sources. After 6 weeks feeding period, all calves were slaughtered and the weights and chemical composition of the visceral free carcasses (VFC, including head, hide, feet and tail) were determined. Gain of BW (0.38, 0.45, 0.56 and 0.62kg/d) and gain: feed ratio (0.51, 0.59, 0.71 and 0.78) increased linearly ($P<0.001$) as dietary CP increased; rate of change in body length, wither height, and heart girth also increased linearly ($P\leq0.05$). Balance

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measurements conducted during week three and week four of the experimental period showed that both absorbed and retained N (7.6, 9.0, 13.2, and 15.6g/d) increased linearly (P<0.001) as dietary CP increased. Retained N as a percentage of absorbed N increased linearly (P<0.01) as dietary CP increased (44.3, 44.7, 50.7 and 50.9%), whereas biological value (BV) was unaffected (71.1, 68.7, 69.5, and 67.3%; P=0.26). Digestible energy and ME represented 94.55 and 89.7% of intake energy, respectively, and were not affected dietary CP content. Plasma urea N concentration increased linearly (2.9, 3.3, 4.6, and 6.0mg/dL) as dietary CP increased. Contents of water (68.2, 69.1, 70.2, and 70.5%; P<0.001) and protein (19.6, 20.0, 20.0, and 20.2%; P<0.10) in VFC increased linearly, whereas contents of fat (7.2, 6.2, 5.5, and 5.2%; P<0.001) and ash (5.1, 5.2, 4.8, and 4.7%; P<0.02) decreased linearly as dietary CP increased. Trends in visceral tissue composition were similar to those for VFC. The content of the water in VFC tissue increased, whereas contents of fat and energy decreased, as dietary CP increased (Blome et al. 2003). Dietary CP did not affect final VFC energy and gain of energy in VFC. At similar initial ME intakes, increasing dietary CP (i.e., increasing protein: energy) linearly increased average daily gain (ADG), gain : feed, nitrogen retention, and deposition of lean tissue in VFC demonstrating that diet composition can markedly affect component of body growth, in pre-ruminant dairy calves (Blome *et al,*. 2003).

Sadeghi & Tabietjien (2005) examined the effects of tallow supplementation and reducing protein level on broiler chickens performance. A total of 480 one-day-old broiler chicks of a commercial strain (Arian) from both sex with equal ratio were placed in 32 pens, 15 in each pen. Treatments were included tallow at 0, 2.5, 5 and 7.5% levels and protein level reduction in NRC energy diets as ME to CP ratio increased 10 unit. Each treatment replicated 4 times. ME of tallow was determined by Sibbald method. Results showed that AME_n value of tallow was 7150kcal kg^{-1}. In whole production period (days 7-56) chicks that were fed with a diet containing NRC protein level, adding 5 and 7.5% tallow significantly (P<0.05) increased feed intake but in reduced protein diets, adding tallow could not affect feed intake.

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Feeding different levels of tallow and diet protein reduction in both low and high-energy diets had no significant effect on weight gain in ages 1 to 21 and 42 to 56 and 7 to 56. There was no significant difference in feed conversion ratio in chicks fed with different experimental diets in all ages. Carcass, liver and abdominal fat was not affected by experimental treatments. The results show that adding 2.5% tallow to a diet with a protein level according to NRC recommendation results in better performance.

Broderick (2003) conducted an experiment to quantify the dietary concentrations of protein and energy under standard feeding conditions that would minimize N excretion without depressing the yield of milk and milk components. Forty-five multiparous and 18 primiparous Holstein cows were fed three levels of crude proteins (CP), each at three levels of neutral detergents fiber (NDF), to identify optimal dietary CP and energy. Cows were blocked by parity and days in milk into 7 groups of nine and randomly assigned to an incomplete 9x9 Latin square trial with four 4-wk periods. Diets were formulated from alfalfa and corn silages, high-moisture corn, soybean meal, minerals, and vitamins. Forage was 60% alfalfa and 40% corn silage on all diets; NDF contents of 36, 32, and 28% were obtained by feeding 75, 63, and 50% forage, respectively. Dietary CP contents of 15.1, 16.7, and 18.4% were obtained by replacing high-moisture corn with soya-bean meal. Production data were from the last two weeks of each period. Spot fecal and urine samples were collected from 36 cows to estimate N excretion using fecal indigestible acid detergent fiber (ADF) and urinary creatinine as markers. There were no interactions ($p > 0.08$) between dietary CP and NDF for any trait; thus, effects of CP were not confounded by NDF and vice versa. Intake of DM and fat yield were lower on 15.1% CP than at higher CP (Broderick 2003). There were linear increases in milk urea and urinary N excretion and linear decreases in N efficiency with increasing CP. Increasing CP from 15.1 to 18.4% reduced milk N from 31 to 25% of dietary N, increased urinary N from 23 to 35% of dietary N, and reduced fecal N from 45 to 41% of dietary N. Decreasing NDF gave linear increases in BW gain, yield of milk, protein, true protein, lactose, and SNF, and

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milk/DM intake and milk N/N intake, and linear decreases in milk urea N. However, fat yield was lower on 28% than 32% NDF. Reducing NDF from 36 to 28% increased purine derivative excretion by 19%, suggesting increased microbial protein. Increasing CP by adding soya-bean meal to diets fed cows averaging 34kg/d of milk increased intake and fat yield but depressed N efficiency. Increasing dietary energy, by reducing forage improved milk yield and efficiency and decreased excretion of environmentally labile urinary N (Broderick 2003).

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CHAPTER 3

MATERIALS AND METHODS

3.1 Animals

Four to five months old emu chicks were obtained from African Emu Ranch. The birds were selected in October 2004 with an average starting weight of 11.09 kg and were reared to a target weight of approximately 30 kg before starting the feeding trial. The birds were raised on the trial site and so acclimatization to the location was not a problem. It is the farm's practice to individually microchip all the birds, thus identification was by scanning the chips. A total number of twenty-six birds (see Appendix 2, for ID's and gender) were camped and fed with the control feed pellets containing 17% crude protein twice a day at a rate of 1.5 – 2kg/bird.

3.2 Growth

The birds were weighed fortnightly from April 2005 to December 2005 before the feeding trial started and the average growth during pre-trial period is illustrated in Figure 3.1

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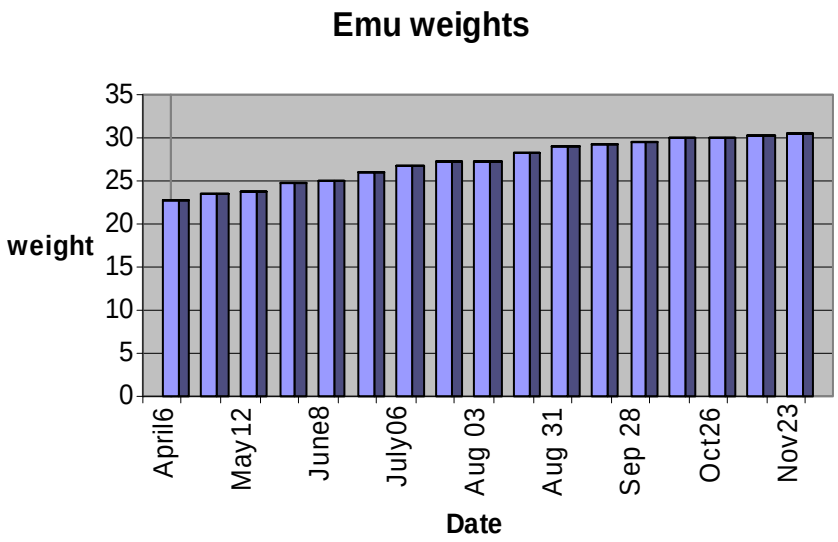
Figure 3.1: Average growth rate of the birds on 17% CP, before the feeding trial (weight in kg).



3.3 Feed

Feed was purchased from Rustier feed company in Rustenburg, Northwest Province. The feed for the trial was formulated to contain 14, and 20% crude protein (CP) contents for the respective treatments. The main ingredients of the feed included hominy chops, yellow maize, sunflower, wheat bran and gluten. Proximate analysis of these ingredients is shown in Table 3.1.

The treatment diets were specially formulated to contain 14 & 20% CP with more or less equal levels of energy as the control diet, as shown below. The energy level was more or less the same for all the diets and therefore equal to that of the control. Even though CP was part of the formula, (the proximate analysis in Table 3.2) values of ME at different levels of CP were not significantly different.

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Control diet and the treatment diets

1. Control diet : 17% CP Energy at 11.58 MJ
2. Protein level 1 : 14 % CP Energy at 12.03 MJ
3. Protein level 2 : 20% CP Energy at 11.58 MJ

Table 3.1: Ingredients and their contribution to the emu rations

Description	DM (g/100g)	Moist (g/100g)	Ash (g/100g)	CP (g/100g)	CF (g/100 g)	CF (g/100g)	GE (MJ/kg)	EE	NFE	ME (MJ/kg)
Hominy Chop	87.7	12.3	2.42	9.66	8.83	8.2	17.3	9.40	67.98	14.91
Yellow Maize	89.8	10.2	1.01	7.44	3.16	3.3	16.5	3.64	83.79	14.78
SOC (sunflower)	94.3	5.7	5.53	32.9	28.13	2.1	18.3	2.19	28.92	10.12
Wheat Bran	90.3	9.7	4.92	16.9	10.15	5.4	17.4	5.96	59.75	13.61
Wheat Gluten	88.3	11.7	5.24	21.2	9.89	3.3	16.9	3.71	56.46	13.10

DM: Dry matter; CP: Crude protein; CF: Crude fibre; GE: Gross energy; EE: Ether extract; NFE: Nitrogen free extract;ME: Metabolizable energy

3.3.1 Collection of feed samples

Twenty, 50 kg bags of feed were bought for each treatment group and the control. The crude protein content, 20 & 14% for the treatment groups and 17% for the control, which were delivered by the feed company, were confirmed by taking composite representative samples of the feed to the Nutrilab of the Animal and Wildlife Sciences Department, University of Pretoria. Five bags were from the first, fifth, tenth, fifteenth and twentieth of the 20 bags of each treatment. All the 5 bags representing one treatment e.g. 20% CP were opened and equal amounts of the feed from top, middle and bottom parts of each of the 5bags were scooped and mixed to form one sample for that treatment. One-kilogram samples of each treatment were thus prepared and analyzed to confirm the percentage composition of the feed in respect of crude protein (CP), nitrogen free extract (NFE) and ether extract or (EE) % for calculation of metabolizable energy (ME) of feed samples. The remaining amounts of the samples were kept for possible future laboratory analyses. The details of the results of the proximate analysis are presented in the table below. The feed was ready for use at the end of November 2005. A second

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proximate analysis was performed on samples of feed actually fed during the feeding trial to confirm that the nutrient content was correct. The levels of CP in the respective treatments are indicated in the Table 3.2 below.

Table 3.2.: Proximate analysis of rations

"AS IS" BASIS	***ANALYSIS***						
	Dry matter (g/100g)	**Moisture (g/100g)**	**Ash (g/100g)**	**Crude protein (g/100g)***	**Crude fibre (g/100g)**	**Crude fat (g/100g)**	**Gross energy (MJ/kg)**
Sample (14%)	90.49	9.51	8.36	13.15	7.82	4.56	15.9
Sample (17%)	91.6	8.4	8.6	17.3	9.29	4.79	16.1
Sample (20%)	91.1	8.9	7.7	20.5	9.24	4.16	16.4
DM BASIS	**ANALYSIS**						
Sample (14%)	100	0	9.24	14.53	8.65	5.04	17.5
Sample (17%)	100	0	9.4	18.9	10.1	5.2	17.6
Sample (20%)	100	0	8.4	22.5	10.1	4.6	18.0

The "Dumas" method was used in the crude protein analysis.

Metabolisable energy: ME = [(3.5*CP) + (8.5*CF) + (3.5*NFE)]*10*4.184

Table 3.3: Proximate analysis of rations and the determination of ME

"AS IS" BASIS	**ANALYSIS**			
	Crude protein	**Ether extract**	**Nitrogen free extract**	**Metabolisable energy (MJ/kg)**
14% sample	13.15	4.56	61.63	12.03
17% sample	17.03	5.51	48.69	11.58
20% sample	20.55	5.51	48.69	11.58
DM BASIS	**ANALYSIS**			
14% cp sample	14.53	5.04	63.92	13.28
17% cp sample	18.34	5.93	52.42	12.47
20% cp sample	18.34	5.93	52.42	12.47

NFE= 100% - (% Ash + % CP + %EE + % CF)

3.4 Livestock husbandry

3.4.1 Experimental camp management

Before the onset of the trial, a camp was set up on the farm for the experiment. The structure of the camps with the 3 groups is illustrated in Figure 3.2. The camp consisted of three mini-camp areas, passages and a weighing area with a weighing

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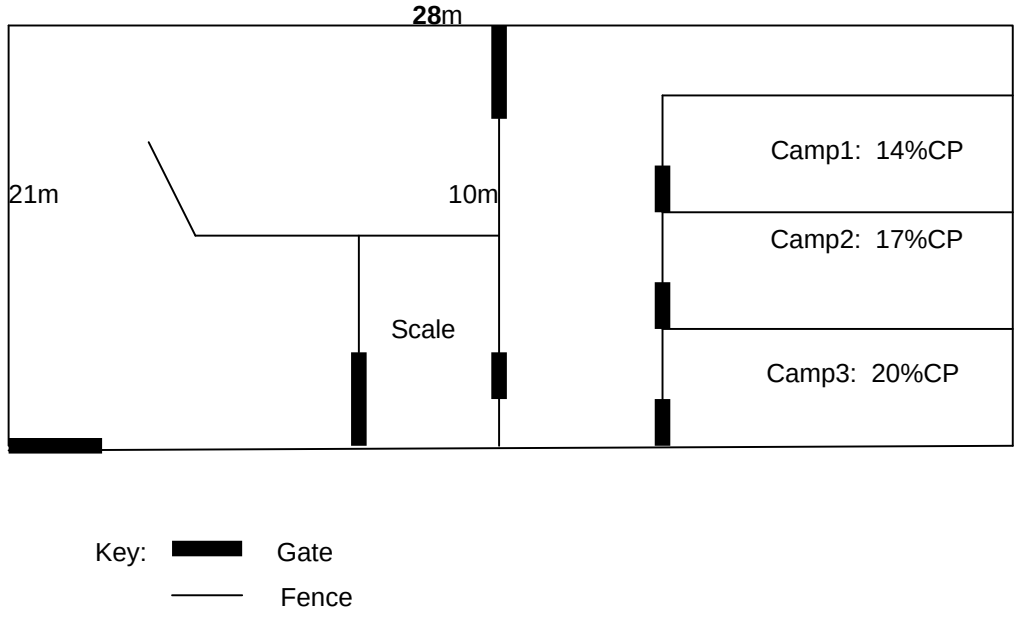
scale for weighing of the birds. The various sections of the camps were controlled by gates.

3.4.2 Grouping of birds

On 14 September 2005 all birds were weighed and randomly allocated into three groups with eight birds per group. The two smallest birds were removed from the original 26 since 24 were required to have an equal number of 8 birds in each group (balanced experimental design). The ratio between male and female was also balanced. The birds were randomly assigned to the two treatment groups (20% and 14%) and the control group (17% CP) respectively. The aim of the groupings at that stage was to allow the birds to adapt to their respective environments as well as to each other. Appendix 3 shows 24 micro-chipped birds assigned to the two different treatments and the control.

Figure 3.2: Set-up of camps



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3.5 Feeding trial programme

Birds in all the three mini-camps or sections were granted enough space for free movement. Each camp was provided with two feeding troughs and two water troughs. The feeding commenced on the 9 December 2005. The feeding was *ad libitum* in all the camps. The researcher and a farm manager ensured that enough feed was always available in the feeding troughs. Even though the groupings were done on September 2005, the birds were still fed with the control diet till 8 December 2005. It took over two months to start with the new diets after the groupings because of the delay in confirmation of the 14% CP batch from the company that twice proved to have a higher content than claimed.

The feeding programme began on the 9 Dec 2005 until 9 February 2005. Birds in the three experimental groups were fed *ad libitum* with pelleted feeds and water. Feed was replenished every morning with some additions in the afternoons when it was deemed necessary during monitoring. The weights of the birds were recorded every fortnight during the feeding trial (average weights of emus are shown in Table 3.3). Every morning, leftovers in the feeding troughs were carefully collected, weighed and recorded. The feeding troughs were cleaned. Fresh feed was then weighed, recorded and poured into the troughs. Consumption of pellets per day was recorded for each group as feed given per day minus leftovers before the next feeding. In times of rain, the wet conditions made it impossible to determine the leftovers. The atmospheric condition with regards to temperature and humidity were presumed homogeneous in all the camps at any point in time. In order to assess the feed consumption rate, observations were recorded using the data sheet shown in Appendix 4 as follows:

- Date/Day
- Weather conditions
- Amount of feed given
- Left-over per day
- Feed consumed per day

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– Remarks/observations

Table 3.4: Average weights of emus during the feeding trial.

GROUP 1: 20% CP					
DATE	**Dec 07**	**Dec 21**	**Jan 04**	**Jan 18**	**Feb 23**
AVG. WTS	**29.69**	**29.7**	**30.44**	**30.63**	**33.46**
GROUP 2: 17% CP					
DATE	**Dec 07**	**Dec 21**	**Jan 04**	**Jan 18**	**Feb 23**
AVG. WTS	**32.1**	**33.13**	**34.2**	**34.4**	**35.4**
GROUP 3: 14% CP					
DATE	**Dec 07**	**Dec 21**	**Jan 04**	**Jan 18**	**Feb 23**
AVG. WTS	**31.14**	**32.5**	**32.91**	**33.4**	**34.55**

3.6 Slaughter

At the end of the feeding trial, all the 24 birds were slaughtered (Figure 3.3 and details below).

Figure 3.3: Picture showing emus during slaughter

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(a) Stunning

The slaughter process was made up of seven stages, which were strictly supervised. The stunning was done to ensure humane slaughter and to minimize stress to the animals and to comply with the law (Animal protection act, 1962). Birds were moved to the stunning facility or box via a race in a single file into a restraining passage. The birds were guided and held in the stunning box. The feet were restrained to eliminate kicking. Time span between stunning and bleeding did not exceed 60 seconds. Stunning parameters were checked and the back-up stunner was in a working condition. Stunning parameters: 120 milli amperes and 220-350 volts – 4 to 6 seconds 350 milli amperes 110 volts – 12 seconds. Trained stunner and workers were in charge of the process.

(b) Shackling and hoisting

This procedure was done to ensure that the bleeding was complete within 45 seconds.

Before stunning, the legs of the bird were restrained. The workers shackled both toes with a chain specially designed for this purpose. The chain was then hooked onto the overhead hoisting apparatus. The birds were hoisted and pulled to the bleeding trough.

(c) Bleeding

- In humane slaughter, exsanguination is actually what kills the animal. The better the bleeding the longer the shelve life of the carcass before refrigeration is necessary.
  - A two incision system was used for bleeding the birds; with a sterilized knife placed horizontally incision through the neck region, under the head, to ensure that all main jugular veins are cut in order to facilitate proper and acceptable bleeding.
  - A second incision in the neck area with a clean sterilized knife and with a stabbing action opens up the arteries in the thoracic area to facilitate bleeding and knife was sterilized after each bird.

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(d) Feather plucking

This process was done to ensure that the feathers were removed from the carcass line and to eliminate contamination by feathers' dust or other contaminants. After a period of less than six minutes of bleeding time, the carcasses were moved into the feather plucking area. All feathers were removed to ensure clean carcass. The large wing and tail feathers and other feathers were removed and stacked in plastic bag and the plastic bags were removed immediately. The door between the feather plucking area and the skinning was closed at all times. It was only opened to pass plucked carcasses through at intervals.. As this area became dirty quickly, the supervisor insisted on continuous cleaning in this area. All personnel were putting on face- masks (Animal health and safety act, 1998).

(e) Skinning

The line workers at the abattoir are trained in this procedure and this helps to minimize any contamination from the skin, hands, platforms and utensils. The head and wings were removed

Contamination of carcasses during head and wing tip removal was prevented. Spear cut on the neck and wings was performed inside out and knife sterilized after each spear cut incision.

The following were ensured:

- No contact between dirty hands and exposed meat
- No contact between exposed meat and rails
- Carcasses were spaced and did not touched each other
- Two knife method between hide cut and undermining/skinning, hide folded away from exposed flesh
- Hide did not come into contact with exposed flesh
- Hide did not swing freely after removal
- Carcasses were not allowed to touch platforms
- Bag used over the end of the neck

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- Regular cleaning of hands, forearms and aprons
- Dirty hands must not come in contact with exposed meat

After transfer, the roller hooks and gambrels return to the dirty area. Only clean roller hooks and gambrels are used.

(f) Evisceration

Trained operator did this procedure hygienically. This procedure was done about 45 minutes after stunning.

(g) Carcass inspection (approval)

This was done by a veterinary representative while the carcass was on the hoists and in the detention area.

3.7 Sample collection

After evisceration, the gastrointestinal tract contents, segment by segment (proventriculus, proximal intestine, and distal intestine, caeca and colon), were collected and put in labeled plastic bottles. They were transported in a cooler box on ice. They were stored at -20 ^{o}C until extraction and analysis.

3.8 Data analysis

The following data was recorded for emu in all groups;

- The weights of the birds before and during the trial
- The dressed-out carcass weight
- Intestinal content
    - Volatile fatty acids
    - Electrolytes
- Intestinal segments
    - Length
    - Weights
    - Fat yields
        - Fat composition

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- Long chain fatty acids
- Lipid content

The data was analyzed by repeated measures using ANOVA procedures on SPSS version 8. The level of significance was set at $P< 0.05$ for all the statistical analyses performed. This research conforms to the ethical norms and standards of the Faculty of Veterinary Science at the University of Pretoria.

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CHAPTER 4

RESULTS

4.1 Feeding

Group 1 (20% CP, Treatment 1)

The feed consumption per day for the group for the period 9 December 2005 to 22 February 2006 was on the downward trend under warm and no rain conditions. The feed consumption for this group went as high as 8kg/day and decreased to as low as 2.5kg/day and 3.3kg/day in some of the days resulting in high levels of leftovers. This trend could be attributed to a lot of fighting among the birds in this group. Consumption per day started to increase when the birds stopped the fighting and settled down. Feed consumption per day was very poor between 31 December 2005 and 13 January 2006 due to continuous rain and this was during the treatment period. Consumption/day was generally low under wet conditions and very good under warm and/ or cloudy days with no rain, between 14 January 2006 and 22 February 2006, recording as high as 8.8kg per group per day. Unfortunately one of the birds from the 20% CP group had to be put down due to poor recovery from a severe injury sustained during fighting.

Group 2 (17% CP, Control diet)

The feed consumption per day for the group for the period 9 to 30 December 2005 rose from initial 8kg/day to, as high as 16kg/day and slightly lowered to 13.1kg/day on the 30 December 2005 just before the on-set of the rain. The initial good consumption per day by this group could possibly be due to the fact that there was no fighting among the birds and, of course, the control diet was their normal diet. Consumption per day by the group reduced to about 9-5.7kg/day between 30 December 2005 and 26 January 2006 due to wet conditions caused by the continuous rain. There was uneven consumption per day from 27 January 2006 to 22 February 2006 with an average of about 7kg/day for the group also due to wet conditions as a result of rain. In the same vein consumption/day was generally low

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under wet conditions and very good under warm and/ or cloudy days with no rain, recording as high as 16kg per group per day. The lowest consumption/day by this group was 5.2kg /day.

Group 3 (14 % CP, Treatment 2)

The feed consumption per day for the group for the period 9 to 29 December 2005 rose from initial 8kg/day to as high as 16kg/day and lowered to 8kg/day on the 29 December 2005, that was just before the on-set of the rain. Consumption per day by this group reduced to range between 2kg – 7kg/day between 30 December 2005 and 14 January 2006 due to wet conditions caused by the continuous rain. Thereafter consumption improved under warm days with no rain to between 4.4kg/day -8.9kg on a decreasing trend until 26 January 2006. Consumption picked up again to between 6.9kg/day and 7.62kg/day till the end of the trial under mixed conditions of rain and warm days. Similarly, consumption/day was generally low under wet conditions and very good under warm and/ or cloudy days with no rain, recording as high as 16kg per group per day. The lowest consumption/day by this group was 2kg.

4.2 Growth of emus at different stages

A summary of the results of the birds at different stages under the respective treatments are presented in Table 4.1 and 4.2.

4.2.1 Pre-trial growth/Adaptation period

The single factorial ANOVA analysis of the treatments and gender at the pre-trial period showed no significant difference in growth and average daily weight gains (ADG) between the groups ($F = 0.198$, $p = 0.662$). The results of the two-factor ANOVA of treatment/gender at the same period showed no significant difference between the groups ($F = 0.759$, $p = 0.484$).

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4.2.2 Growth during feeding trial

The growth rate and average weight gain of the birds during the feeding trial under the respective treatments and genders showed no statistically significant difference (F = 0.118, p = 0.890).The results of the analysis of differences in growth and average daily gain between treatments and genders also showed no significant difference between the groups (F = 2.523, p = 0.112).

4.2.3 Emu weights

The weights of the birds before and during the trial for the period from October 16, 2004, and February 23, 2006 are presented in Figure 4.1.

Table 4.1**:** Growth characteristics during pre-trial period

Groups		**Group1**	**Group2**	**Group 3**	**F**	**DF**	**P-value**
Growthrate		2.688±1.804	2.325±1.736	0.400±3.026	0.198	1	0.662
ADG		0.032±0.021	0.028±0.0207	0.005±0.036			
Gender		**Female**		**Male**			
	Growth	1.582±2.5198		2.125±2.252	0.364	1	0.555
	ADG	0.019±0.030		0.025±0.027			
Gender	**Growth rate**						
	Female	1.923±1.127	2.853±1.136	0.316±1.317	0.759	2	0.48
	Male	3.542±1.125	1.823±1.127	0.822±1.159			
ADG	**Female**	0.023±0.013	0.034±0.013	0.004±0.016	0.759	2	0.484
	Male	0.042±0.013	0.022±0.013	0.010±0.014			

Table 4.2**:** Growth characteristics during treatment period

		14%	**17%**	**20%**	**F**	**P-value**
Growth		3.350± 2.447	3.312± 2.621	3.771±2.543	0.118	0.890
ADG		0.044± 0.032	0.043±0.034	0.049±0.033		
Gender		**Female**		**Male**		
	Growth	3.775±3.634		2.925±0.531	0.118	0.890
	ADG	0.049±0.047		0.038±0.007		
Gender						
Growth	**Female**	3.916±1.185	2.309±1.184	5.721±1.385	2.523	0.112
	Male	2.958±1.183	4.366±1.185	2.086±1.219		
ADG	**Female**	0.051±0.015	0.030±0.015	0.074±0.018	2.523	0.112
	Male	0.038±0.015	0.057±0.015	0.027±0.016		

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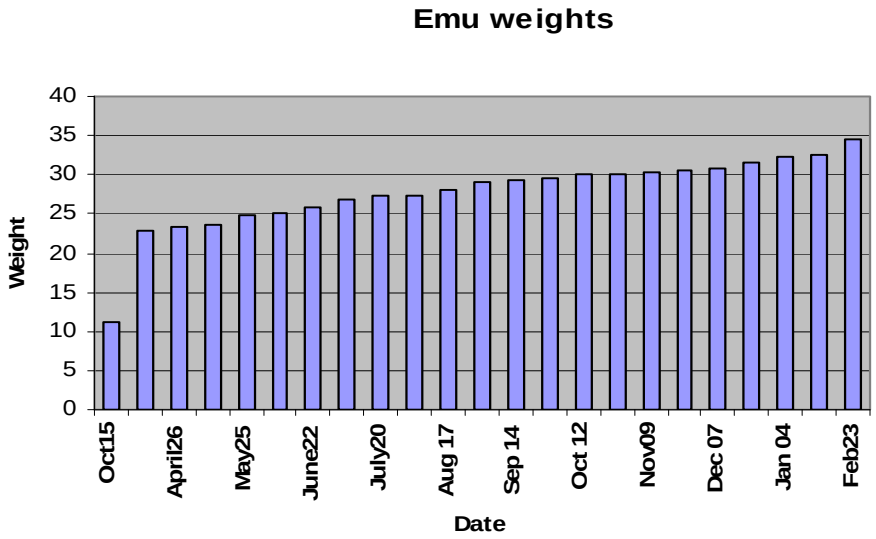
Figure 4.1: Emu weights from pre-trial to the end of feeding trial



4.3 Dressed-out carcass weight

Results of dressed-out carcass weight as well as percent carcass weight are presented in Table 4.3 and 4.4. The results of the statistical analysis of the treatment one-way ANOVA showed that there was a significant difference between the respective groups with regards to dressed-out carcass weight ($F=4.493$, $p = 0.028$) but there was no significant difference between the treatments on the basis of gender ($F=1.825$, $p = 0.196$). The percent carcass weight between the groups with respect to treatment/gender showed no significant difference ($F=1.244$, $p = 0.315$). Similarly the results of one-way ANOVA indicated that there was a significant difference between the respective groups with regards to dressing percentage ($p = 0.033$), however there was no significant difference between the treatments on the basis of gender ($p=0.835$ and 0.348 respectively for females and males).

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Table 4.3**:** Dressed-out carcass weight (kg) of emus.

Treatment	**14%**	**17%**	**20%**	**F**	**DF**	**P-value**
Carcass weight	16.75±1.325	18.65±2.013	19.108±1.629	4.493	1	0.028
Gender						
Female	16.85±1.684	18.70±1.996	20.45±0.848	1.825	1	0.196
Male	16.65±1.112	18.60±2.338	18.10±1.290			
Gender						
Female	16.891±0.844	18.673±0.843	20.576±0.986	1.244	2	0.315
Male	16.660±0.842	18.641±0.844	17.943±0.868			

Table 4.4: Dressing percentage of emus

	14%	**17%**	**20%**	**F**	**DF**	**P-value**
%age	48.79±4.47	53.04±6.08	57.83±9.09	4.248	1	0.033
Gender						
Female	46.82±3.63	51.27±5.96	62.04±12.37	0.045	1	0.835
Male	50.76±4.817	54.81±6.51	54.66±5.67			
Gender						
Female	46.55±3.25	51.44±3.24	61.21±3.79	1.127	2	0.348
Male	50.70±3.24	54.53±3.25	55.73±3.34			

4.4 The digestive tract segments and their contents

Detailed results of the analysis of the "with and without" contents of the digestive tract segments are presented in Table 4.5. The results showed that there were no significant differences between the groups (of the subject factors) in terms of the respective anatomical segments of the digestive tract.

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Table 4.5.: The effects of the different diets on the weight of the digestive tract segments "with & without" contents (g).

	14%	17%	20%	DF	F	P-Value
Proventriculus (with contents)	0.503±0.107	0.5188±0.180	0.520±0.119	1	0.047	0.954
Gender: Female	0.468±0.047	0.563±0.161	0.610±0.079	1	2.018	0.175
Male	0.538±0.146	0.475±0.212	0.453±0.100			
Treatment/ Gender						
Female	0.476±0.063	0.557±0.063	0.636±0.074	2	2.234	0.139
Male	0.540±0.063	0.484±0.063	0.419±0.065			
Proventriculus (without contents)	0.503±0.107	0.510±0.181	0.520±0.119	1	0.048	0.953
Gender: Female	0.463±0.047	0.550±0.161	0.610±0.79			
Male	0.533±0.146	0.470±0.213	0.453±0.100	1	1.959	0.181
Treatment/ Gender						
Female	0.477±0.063	0.544±0.062	0.638±0.073			
Male	0.540±0.062	0.479±0.063	0.417±0.064	2	2.299	0.139
Proximal Intestine(with contents)	0.410±0.101	0.375±0.114	0.407±0.118	2	0.251	0.781
Gender: Female	0.445±0.127	0.428±0.129	0.437±0.135			
Male	0.375±0.067	0.323±0.082	0.385±0.119	1	2.753	0.117
Treatment/ Gender						
Female	0.447±0.057	0.426±0.057	0.443±0.067	2	0.049	0.953
Male	0.376±0.057	0.325±0.057	0.376±0.059			
Proximal intestine (without contents)	0.241±0.098	0.219±0.086	0.194±0.042	2	0.621	0.550
Gender: Female	0.288±0.118	0.208±0.113	0.190±0.034	1	0.417	0.527
Male	0.195±0.053	0.230±0.067	0.197±0.523			
Treatment/ Gender						
Female	0.289±0.042	0.207±0.042	0.193±0.049	2	1.092	0.359
Male	0.195±0.042	0.231±0.042	0.193±0.043			
Distal intestine (with contents)	0.500+0.161	0.385+0.184	0.417+0.194	2	1.089	0.360
Gender: Female	0.483+0.118	0.465+0.236	0.547+0.231	1	3.819	0.068
Male	0.518+0.213	0.305+0.079	0.320+0.104			
Treatment/ Gender						
Female	0.492/0.082	0.459+0.082	0.574+0.095	2	1.712	0.212
Male	0.052/0.082	0.314+0.082	0.285+0.084			
Distal intestine (without contents)	0.294+0.198	0.204+0.083	0.243+0.098	2	0.712	0.506
Gender: Female	0.278+0.140	0.180+0.080	0.277+0.035	1	0.007	0.935
Male	0.310+0.266	0.228+0.092	0.218+0.127			
Treatment/ Gender						
Female	0.278+0.076	0.179+0.076	0.279+0.089	2	0.276	0.762
Male	0.310+0.076	0.228+0.076	0.214+0.078			

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4.5 Electrolytes concentration

The descriptive statistics for potassium concentration are shown in Table 4.6 below. Potassium level was used as the dependent variable with dietary treatment and anatomical locations as independent variables. The results indicate that the differences in electrolyte content in different anatomical locations or segments were not significant at the 5% significance level (p=0.211). Potassium concentration values from the proventriculus samples of the treatment groups could not be determined as they could not get enough fluid. Sodium and Chloride concentration could not be determined because of the same problem of not enough little fluid.

Table 4.6**:** Potassium concentration in the different parts of the gastrointestinal tract

	Anatomical location	**14%**	**17%**	**20%**	**P-value**
K	Colon/Caeca	51.50± 0.00	19.52± 10.74	26.55± 3.75	0.211
	Distal intestine	40.88 ± 15.37	30.01± 13.55	45.47± 8.01	
	Proventriculus	-	23.00± 0.00	-	
	Proximal intestine	27.23± 21.03	31.81±12.08	40.16+ 11.02	

4.6 Volatile Fatty Acids

The results of the analysis of the fatty acids are shown in Table 4.7 below. The results show that the difference between the percentage of acetic acid in the distal and proximal segments of the intestine for the respective treatments are insignificant (F=1.291, p=0.289). As can be seen from the table, the F statistic was insignificant meaning that the treatments do not have significant effects on the acid levels. The standard deviations were minimal. The results further show that the difference between the percentage of propionic acid in the distal and proximal

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segments of the intestine for the respective treatments are insignificant (F=1.723, p=0.195). The difference between the percentage of iso-butyric acid in the distal and proximal segments of the intestine for the respective treatments are insignificant (F=0.135, p=0.874). The difference between the percentage of butyric acid in the distal and proximal segments of the intestine for the respective treatments are insignificant (F=0.126, p=0.882). The results show that the difference between the percentage of valeric acid in the distal and proximal segments of the intestine for the respective treatments are insignificant (F=0.947, p=0.399).

Table 4.7: Results of volatile fatty acids concentration in the different parts of the intestine for the control and the treatments diet.

Type	Origin	14%	17%	20%	DF	F	P-value
Acetic acid	Distal intestine	79.427±6.94	68.060±6.60	74.125±6.154	2	1.291	0.289
	Proximal intestine	72.856±12.024	70.78±6.77	70.17±6.08			
Propionic acid	Distal intestine	14.505±6.036	23.614±4.269	17.751±7.31	2	1.723	0.195
	Proximal intestine	21.36±9.57	21.64±5.64	22.57±4.51			
Iso-butyric acid	Distal intestine	0.958±0.935	1.387±0.775	1.288±0.463	2	0.135	0.874
	Proximal intestine	1.32±0.89	1.44±0.89	1.60±0.86			
Butyric acid	Distal intestine	4.510±1.638	5.274± 3.578	5.670±3.075	2	0.126	0.882
	Proximal intestine	3.18±1.11	4.74±2.52	4.32±0.85			
Valeric acid	Distal intestine	0.600±0.267	1.664±0.702	1.148±0.687	2	0.947	0.399
	Proximal intestine	1.31±1.28	1.39±1.03	1.34±1.08			

4.7 Fat

Detailed results of the fat analysis are presented in Table 4.8.1, 4.8.2, 4.8.3, and 4.8.4. The results of the subcutaneous fat showed a significant difference between the groups with respect to the subject factors. However, the results of the treatment/gender analysis showed no significant difference between the groups. The results of the skin fat regarding treatment also showed significant difference

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between the groups. However, the results indicate that, there is no significant difference between the groups regarding treatment/gender. The variations among the standard deviations are minimal. The results of the omental fat for both between and within analysis respectively were significant. The results of the total fat analysis however, indicated that there is no significant difference in the fat between and within the group.

Table 4.8.: Subcutaneous fat content (kg) of emus fed different dietary protein levels

	Diet				
	14%	**17%**	**20%**	**F**	**P-value**
Yield	1.10±0.37	3.45±2.48	3.37±1.93	29.67	0.000
Gender					
Female	1.05±0.25	3.90±2.92	2.60±1.22	1.223	0.285
Male	1.15±0.50	3.00±2.30	3.95±2.32		
Gender					
Female	1.29±0.31	3.74±0.31	3.32±0.37	0.223	0.803
Male	1.21±0.31	3.24±0.31	3.03±0.32		

Table 4.9: Skin fat content (kg) of the emus fed different dietary protein levels

	Diet				
	14%	**17%**	**20%**	**F**	**P-value**
Yield	2.28±0.21	0.36±0.14	0.74±0.84	30.62	0.000
Gender					
Female	2.38±0.13	0.30±0.08	0.50±0.26	0.34	0.570
Male	2.18±0.24	0.43±0.17	0.93±1.13		
Gender					
Female	2.37±0.26	0.30±0.26	0.48±0.30	0.732	0.496
Male	2.17±0.26	0.42±0.26	0.93±0.27		

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Table 4.10: Omental fat content (kg) of the emus on the different diets

	Diet				
	14%	**17%**	**20%**	**F**	**P-value**
Yield	0.68±0.29	0.36±0.28	0.33±0.29	5.830	0.013
Gender					
Female	0.54±0.15	0.18±0.21	0.35±0.37	2.765	0.116
Male	0.83±0.34	0.54±0.25	0.31±0.28		
Gender					
Female	0.56±0.11	0.17±0.11	0.41±0.14	2.710	0.097
Male	0.84±0.11	0.56±0.11	0.24±0.12		

Table 4.11: Average fat yield (kg) produced by the birds in the control and treatment groups

	14%	**17%**	**20%**	**F**	**DF**	**P-value**
Total Fat	4.05	4.1	4.45	0.087	2	0.917

4.7.1 Long-chain fatty acids

Detailed results of the analysis of the fat in respect of the long-chain fatty acids are presented in Table 4.8.5. Fat from the omental and subcutaneous areas were collected and analyzed for the long-chain fatty acid contents. The standard deviations were minimal. However, there are no significant differences between the groups or treatments for all the different long chain fatty acids. Detailed results of the analysis of the saturated fatty acids (27.74%), monounsaturated fatty acids (51.80%), and polyunsaturated fatty acids (20.45%) are presented in the lower section of Table 4.8.5. The ratio of unsaturated to saturated acids was 2.60:1 which was not statistically different between the treatment groups. The results indicate that there was no significant difference between the treatment groups for the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA). The standard deviations were minimal.

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Table 4.12**:** Results of long-chain fatty acids analysis in omental and subcutaneous fat from the control and the two treatment groups

Type	Location	14%	17%	20%	F	DF	P-value
C14:0	Omental	0.22±0.15	0.41±0.023	0.26±0.11			
	Subcutaneous	0.17±0.00	0.23±0.134	0.31±0.01	2	1.726	0.269
C16:0	Omental	19.76±1.03	21.86±1.82	19.82±1.03			
	Subcutaneous	21.47±2.17	20.88±0.57	22.63±0.03	2	0.406	0.0686
C16:1	Omental	2.24±0.49	2.79±1.05	2.92±0.23			
	Subcutaneous	2.78±0.99	2.44±0.22	3.26±0.75	2	0.640	0.566
C18:0	Omental	0.22±0.15	0.41±0.023	0.26±0.11			
	Subcutaneous	0.17±0.00	0.23±0.134	0.31±0.01	2	1.016	0.426
C18:1n9t	Omental	0.06±0.02	0.21±0.00	0.11±0.08			
	Subcutaneous	0.09±0.021	0.09±0.06	0.09±0.014	2	3.668	0.105
C18:1n9c	Omental	0.02±0.14	0.41±0.023	0.26±0.11			
	Subcutaneous	0.09±0.021	0.23±0.1	0.31±0.01	2	0.175	0.845
C18:2n6t	Omental	0.04±0.00	0.05±0.02	0.06±0.00			
	Subcutaneous	0.05±0.21	0.04±0.00	0.31±0.01	2	0.619	0.575
C18:2n6c	Omental	22.68±2.55	20.42±3.25	19.81±0.07			
	Subcutaneous	20.92±2.32	22.35±3.15	22.53±0.37	2	0.056	0.946
C18:3n3	Omental	0.22±0.15	0.35±0.00	0.38±0.01			
	Subcutaneous	0.46±0.05	0.47±0.20	0.51±0.02	2	0.300	0.7.53
C20:0	Omental	0.05±0.01	0.07±0.01	0.04±0.00			
	Subcutaneous	0.05±0.04	0.08±0.21	0.05±0.00	2	2.195	0.207
C20:1	Omental	0.16±0.08	0.18±0.02	0.17±0.01			
	Subcutaneous	0.14±0.09	0.12±0.02	0.09±0.03	2	0.052	0.950
C20:2p	Omental	0.12±0.01	0.11±0.00	0.11±0.06			
	Subcutaneous	0.09±0.01	0.11±0.00	0.14±0.08	2	0.299	0.754
C20:4n6	Omental	0.08±0.04	0.07±0.01	0.08±0.01			
	Subcutaneous	0.06±0.01	0.07±0.01	0.07±0.03	2	0.149	0.866
SFA-P	Omental	28.64±0.29	30.76±1.79	28.32±0.81			
	Subcutaneous	29.30±0.27	29.85±1.43	51.24±0.79	2	0.251	0.341
MUFA	Omental	49.96±3.05	48.26±1.47	51.24±0.79			
	Subcutaneous	49.56±3.31	47.20±1.97	46.40±0.81	2	0.251	0.788
PUFA	Omental	24.1±2.76	20.96±3.21	20.44±0.02	2	0.019	0.982

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	Subcutaneous	21.14±3.03	22.96±3.40	23.29±0.35			
	Omental	2.50±0.04	2.26±0.19	2.53±0.10			
UFA-SFA	Subcutaneous	2.41±0.04	2.36±0.16	2.30±0.13	2	1.385	0.332

4.7.2 Lipid content

Detailed results of the analysis of the lipid yields in respect of treatment and anatomical location are presented in Table 4.8.6. Lipid from the omental and subcutaneous areas were collected and analyzed. There was a highly significant difference in the lipid contents of the fat with respect to anatomical location (p=0.0064). The standard deviations varied between 0.32 and 13.4.

Table 4.13: The effect of the different diets on lipid content of omental and subcutaneous fat

	14%	**17%**	**20%**	**Total**	**DF**	**F**	**P**
Location							
Omental	82.3±11.97	83±1.97	82±0.32	82±5.5	1	5.12	0.0064
Subcutaneous	97±0.45	93±6.14	87.19±13.4	92.5±7.98			
Total	89.7±11.04	88.13±6.85	84.35±8.41	87.4±8.42			

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CHAPTER 5

DISCUSSION

5.1 Introduction

Generally feed must contain the proper balance of carbohydrates, proteins, fats, fiber, vitamins and minerals to meet the needs of a particular animal at a given stage of growth or production. Carbohydrates and fats provide energy (metabolizable energy); proteins are needed for tissue growth and repair; fibre is needed for normal bowel function and may be used as a source of energy by adult birds, whose intestines contain the beneficial bacteria necessary for fermentative digestion of fibre. The nutritional requirements of emu have not been sufficiently researched as noted by Minaar (1998).

This research was conducted to study the optimum dietary and energy ratio of finishing diets to sub-adult emu birds for greater fat accretion. Feeding increasing levels of protein *ad libitum* was expected to provide more than the nutritional maintenance requirement of emu. In sub-adult birds the assumption was that the birds have developed the optimum muscle mass and from the emu farmer's point of view, the objective is to encourage these birds to deposit more than protein. Cost-wise, finishing birds at a low 14% and a relatively high energy level would be preferable as this should encourage fat deposition while providing sufficient protein for maintenance and even growth. If the same amount of fat is deposited when compared to diets containing higher protein (17 or 20%), then farmer will save on costs of protein. Under the different levels of CP treatments, it was of interest to observe the effects on growth, fat yield, electrolyte and volatile fatty acid (fermentative digestion) production.

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5.2 Growth analysis

5.2.1 Growth during feeding trial (treatment period)

The growth analysis indicated that the 20% group had the highest growth rate (3.771kg) and the lowest in the 17% group (3.312kg). The ADG was highest in the 20% group (0.049kg) and lowest in the 17% group (0.043kg). This result is in agreement with that found by McGregor & McLaughin (1980) in the Merino sheep. They reported that growth in weaned Merino sheep was highest in the ration containing 20% CP at lower energy concentration. Oboh & Olumese (2008). A similar observation has been reported by Jean, *et al* (2001) in the liver enzymes Aspartate transaminase and Alanine transaminase. They become significantly elevated in animals fed with higher protein diets and that the kidney and liver metabolism of amino acids and nitrogen led to suspiciousor suspected deleterious effects on the function and structure of the organs. In this study the growth and ADG between the treatment groups during the feeding trial period were higher than that of the pre-trial period and this was due to the fact that, during the habituating period it was raining a lot and the emus were not eating properly. That improved during treatment period and they started putting on weight. It is worth noting that the females' growth improved from a pre-trial growth of 1.582kg (on control diet, 17%) to 3.8kg during the feeding trial. The growth of the males' on the other hand increased from 2.125kg during control diet feeding to only 2.925kg during the feeding trial. This showed that the females were bigger at the end of the study than the males. Thus the females were bigger in the end than the males which are normal in the emu Minaar (1998).

5.3 Dressed-out carcass weight and digestive tract segments/contents

The average dressed out carcass weights for 14, 17 & 20 % CP groups were 16.75, 18.65 and 19.11 kg respectively. The results of the statistical analysis of the dressed out carcass weight and percent carcass weight showed that, there was a significant difference between the respective groups. The variations in the standard deviations were not wide. This implies that the carcass weights of birds fed the diet with 20%

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CP were slightly higher than the carcasses of the birds on 17 and 14% CP diets. The results of this study are similar to those of Blake & Hess (2004), who analyzed the effect of protein on growth and carcass yield of emu using 14%, 16% and 18% levels of protein and fixed level of energy. They found that the carcass weight was less in birds fed with lower protein diet (14% CP). This result suggests that, the decision about the type of ration to feed birds depends on the use of the bird, whether it is raised for meat or fat production. However, carcass weights of the females in the present study were greater than those of the males (Table 4.3 & 4.4). This is rather consistent with the results of Blake & Hess (2004) that carcass weights for females were higher than for males.

5.4 Electrolyte concentration

The results indicate that the F-statistic for the anatomical locations or segments was not significant at the 5% level. In the colon/caeca, the K levels were higher in the 14% group (51.50 mmol); followed by the 20% group (26.55mmol) and lastly 17% group (19.52 mmol). In the Distal intestine, the K level was higher in the 20% group (45.47 mmol); followed by the 14% group (40.88mmol) and lastly 17% group (30.01 mmol). With regards to the proximal intestine, the K level was highest in the 20% group (40.16 mmol); followed by the 17% group (31.81mmol) and lastly 14% group (27.23 mmol). The non-significant differences between the treatment groups and locations implies that they were unaffected by the treatments. Skadhauge *et al.,* (1984), measured similar concentrations and osmolality of short chain fatty acids, acetate, Na, K and Cl from samples of contents from the distal small intestine of birds.

5.5 Volatile Fatty acids

The VFA analyzed in the study are acetic acid, propionic acid, iso-butyric acid, butyric acid and valeric acid. In ratites, gaseous substances, such as volatile fatty acids (VFA) and methane are produced by microbial fermentation of fibrous

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compounds in the lower digestive tract. In emus, this takes place in the distal ileum. The proximal large intestine and caeca are the sites of VFA production in ostriches (Herd & Dawson 1984). The large caeca and proximal large intestine are the sites of cellulolysis in rheas (Herd & Dawson 1984). The results show that the difference between the percentage of acetic acid in the distal and proximal segments of the intestine for the respective treatments were insignificant. The results further show that the difference between the percentage of propionic acid in the distal and proximal segments of the intestine for the respective treatments was insignificant. The difference between the percentage of iso-butyric acid in the distal and proximal segments of the intestine for the respective treatments and the control was insignificant . The difference between the percentage of butyric acid in the distal and proximal segments of the intestine for the respective treatments and control diet was insignificant. The results show that the difference between the percentage of valeric acid in the distal and proximal segments of the intestine for the respective treatments and the control were insignificant.

It is worth mentioning that the VFAs collected from the distal and the proximal locations of the intestines consisted predominantly of acetic acid (between 68 and 79.43 mmol). The highest amount of acetic acid (79.43 mmol) was found in the distal intestine confirming the finding of (Herd & Dawson 1984) that microbial fermentation of fibrous compounds in emus takes place in the distal ileum. Acetate was the predominant volatile fatty acid, which suggestive typical foregut fermentation. This finding agrees with that of Scheideler & Angel (1994) who measured volatile fatty acid (VFA) production in the proventriculus of the ostrich.

5.6 Fat yield

Total average fat yield (Subcutaneous fat + Skin fat + Omental fat) for the groups (14, 17 & 20 CP) were 4.06, 4.17 and 4.45 kg respectively. There was no statistically significant difference in the average fat yield between dietary treatment groups. This implies that the average total fat produced by the birds in the 14%

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group was not significantly different from that produced by the birds in the 17 and 20% CP groups. Thus fat yield in emu for this study was maximized at a lower level (14%) of CP in the diet. Fourteen percent CP level in emus' diet implies less feed costs compared to a feed with high CP. The results of this study are similar to those of Minaar (1998), who reported that at 12 to 15 months, emus weighing between 34-39 kg will yield 3-9kg of fat on processing. Similar results were also found in the study done by Hashiguchi & Yamamoto (1998) in Japanese quails. They reported that no differences were observed in the amounts of carcass fat among three groups of Japanese female quails fed with 14, 19 and 20% levels of protein between 42 and 56 days. The low levels of the fat obtained in this study could be attributed to the effects of rain on feed consumption. Another factor was that, the personnel at the slaughter facility were inexperienced, as it was their first time to slaughter emus and harvest fat; hence the fat harvesting process was inefficient leading to loss of some fat. The results indicated that emus fed a low protein to energy ratio in the diet are more efficient in terms of fat deposition. The result is also similar to the findings of Blome, *et al* (2003) regarding growth, nutrient utilization, and body composition of calves fed with milk replacers containing different amounts of protein. One of the findings was that, fat content decreased linearly as dietary CP increased.

However, the analysis of specific location of fat i.e. subcutaneous, skin and omental fat gave different results. The treatment/gender results indicate that the average fat yields of the females under the respective treatments (1.29, 3.74, and 3.32kg) was numerically higher than their corresponding male average fat yields (1.21, 3.24, and 3.03kg) though with no significant difference.

The results also indicate that, there was a significant difference between the treatment groups regarding omental fat. The average omental fat yield of the 14% CP treatment group was the highest (0.68kg) with the lowest in the 20% group (0.33kg). The results on the omental fat yield of the treatment/gender analysis also showed no significant difference among the females and males in the respective

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groups. For 14% group, the average omental fat yield of the males (0.84kg) was higher than that of the females (0.56 kg). In the 17% the average omental fat yield of the males (0.56) was higher than that of the females (0.17kg). However, for the 20% the average omental fat yield of the females (0.41kg) was higher than that of the males (0.24kg). Is important to note that that these figures are low and contradictory because the omental fat contaminated with blood during evisceration had to be discarded.

5.6.1 Long-chain fatty acids

The results of the analysis of the fat in respect of the long-chain fatty acids showed that, there were no significant differences between the groups for all the different long-chain fatty acids. It is known that the body of most ratites prefers to use the long-chain fatty acids for energy. The total unsaturated fatty acids content of the fat was thus 72.25%. The result of this study is consistent with that of Craig-Schmidt, *et al.*, (1995) who reported the fatty acid composition of Emu oil through a study undertaken at Auburn University to characterize the fatty acid composition. The results indicated that Emu oil is highest in monounsaturated fatty acids, with lower amounts of saturated and polyunsaturated fatty acids. Oleic acid (18:1) was found to be the major monounsaturated fatty acid in Emu oil, comprising over 40% of the total fatty acids. Much smaller amounts (less than 5%) of palmitoleic acid (16:1) were found. Major saturated fatty acids in Emu oil were palmitic acid (16:0) which comprised approximately 20% of total fatty acids and stearic acid (18:0) at 8%. Linoleic acid (18:2) at 20% of the total was the primary polyunsaturated fatty acid observed.

In conclusion, approximately 70% of the fatty acids in emu fat were unsaturated. This composition is consistent with current recommendations for a "healthy heart" diet. The monounsaturated fatty acid, oleic acid, was the major fatty acid in emu oil. This fatty acid is a known enhancer for transport of bioactive compounds into the skin, and thus, the fatty acid compositions consistent with emu oil being very penetrating (Craig-Schmidt, *et al.*, 1995).

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5.6.2 Lipid content

It is important to note that not everything that is harvested as fat is fat because there are blood vessels, connective tissue, blood corpuscles etc. etc. hence one talks of lipid content of the harvested fat. The location effect on the lipid content was highly significant. The mean lipid content of the omental and sub-cutaneous fat were 82 ±5.5 % and 92.5 ± 7.98 % respectively. The treatment and location effects were found to be insignificant. Beckerbeur, *et al* (2001) reported that the lipid content of emu oil obtained from the subcutaneous location was 98.8% and 98.0% from the retroperitoneal adipose tissue. There was no effect of diet or gender on the lipid content of the fat. Minaar (1998) has also reported that the quantity of subcutaneous fat is always greater. The overall mean of the lipid produced from both locations is 87.4%. Thus, the lipid content of the fat averaged 87.4 % and the fatty acids analysis showed no significant differences in composition, i.e. monounsaturated, polyunsaturated and saturated fatty acids, between the treatment groups and the control.

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CHAPTER 6

CONCLUSION

The study assessed the effect and interaction of two different levels of protein (14 and 20% CP) and more or less constant energy level on fat deposition. Other analysis performed included: growth, dressed out carcass weights, intestinal segments and contents, VFAs, long chain fatty acids and lipid content of the fat.

The study found the average dressed out carcass weights for 14, 17 & 20 % CP groups to be 16.75, 18.65 and 19.11 kg respectively. The results of the statistical analysis of the dressed out carcass weight showed that, there was significant differences between the respective groups. The percent carcass weight between the groups also showed significant difference, based on this, it may be concluded that if the objective of keeping the emu is for meat production, then it is advisable to feed a high CP diet but maximizing profit will depend on the cost of the protein.

Total average fat yield (Subcutaneous fat + Skin fat + Omental fat) for the groups was 4.1, 4.2 and 4.4 kg respectively. There was no statistically significant difference in the average fat yield per group. It can therefore be concluded that if fat yield is the objective then it will be economical to finish birds on a 14% CP diet. The results of the analysis of the subcutaneous fat showed no significant difference between the groups with respect to the subject factors. Regarding omental fat the results indicate that there was significant difference between the groups. The treatment/gender results showed no significant differences between the males and females.

In conclusion the results suggest that:

- A low dietary protein to energy ration yields the same amount of fat as the high protein diet and
- The quality of fat is not compromised

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The lesser fat obtained (4 to 4.44 kg) in this trial was probably due to poor weather conditions and some anomaly in the fat harvesting process that was beyond the control of the researchers. (Normally the skin is not supposed to be tanned and skin fat is also harvested).

It is recommended that if such a trial is undertaken in future, it must be done in the dry months of the year with strict adherence to the normal fat harvesting procedure.

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APPENDIX 1

Recommended Nutrient Concentration for Emus, Ostriches, and Rheas (the Merck Veterinary Manual, 2003)

Nutrient	Concentration
Protein	20-24%
Arginine	1-3
Lysine	1.2
Methionine	0.35
Methionine + Cystine	0.7
Tryptophan	0.3
Linoleic acid	1.0
Calcium	1.6
Phosphorus, total	1.0
Phosphorus, available	0.8
Potassium	1.1
Sodium	0.2
Magnesium	0.2
Manganese	70 ppm
Zinc	120 ppm
Iron	150 ppm
Copper	20 ppm
Iodine	1 ppm
Selenium	0.3 ppm
Vitamin K	4 ppm
Riboflavin	9 ppm
Pantothenic acid	30 ppm
Niacin	70 ppm
Vitamin B_{12}	0.03 ppm
Choline	1600 ppm
Biotin	0.3 ppm
Folacin	1 ppm
Thiamine	7 ppm
Pyridoxine	5 ppm
Vitamin A	8.000 IU/kg
Cholecalciferol (vitamin D_3)	1.600 IU/kg

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Vitamin E	250 IU/kg
Vitamin K (menadione equivalent)	4 ppm

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APPENDIX 2

List of birds selected and their gender

BIRD IDENTIFICATION	GENDER
4550482C02	Male
4534175763	Male
422E63651A	Male
45345A4610	Male
422E630016	Female
4534270854	Female
430E3C626E	Female
4315505B64	Male
4360104B4F	Male
454F6B1F08	Male
45344125D2C	Male
454A500D25	Female
4463235C15	Female
4533552D5C	Female
455C766508	Female
5033691A1A	Female
4547270534	Female
4537688235C	Female
452F295638	Female
45417F083A	Male
4202630C6F	Male
453372B65	Male
45403B400C	Male
4548457F16	Male
045325C4773	Male

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APPENDIX 3

Grouping of birds

GROUPS		
Treatment 1: 14% Crude Protein Group 3	Control diet: 17% Crude Protein Group 2	Treatment 2: 20% Crude Protein Group 1
5033691A1A	4315505B64	4550482C02
4547270534	4360104B4F	4534175763
4537688235C	454F6B1F08	422E63651A
452F295638	45344125D2C	45345A4610
45417F083A	454A500D25	422E630016
4202630C6F	4463235C15	4534270854
453372B65	4533552D5C	430E3C626E
45403B400C	455C766508	045325C4773

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APPENDIX 4(A)

Feeding: General observations

Group 1 (20% CP)					
DAY	**TEMPCOND**	**FEED/DAY**	**FEEDCONSUMED/DAY**	**LEFT-OVER/DAY**	**OBSRVATION/REMARKS**
9/12/2005	Hot sunny day	8KG	6.5kg	1.5kg	Fighting, not eating much.
10/12/2005	Hot sunny day	8kg	7.3kg	700g	Fighting, not eating much.
11/12/2005	Hot sunny day	8kg	6.4kg	1.6kg	Fighting, not eating much.
12/12/2005	Warm, no rain	9kg	7.3kg	1.7kg	Fighting, not eating much.
005/13/12	Warm, no rain	9kg	6.8kg	2.2kg	Fighting, not eating much
005/14/12	Warm, no rain	8kg	7.4kg	600g	Fighting, not eating much.
005/15/12	Warm, no rain	9kg	8kg	1kg	Fighting, not eating much.
005/16/12	Warm, no rain	9kg	6.9kg	2.1kg	Fighting, not eating much.
005/17/12	Hot sunny day	8kg	2..5kg	5.5kg	Fighting, not eating much.
005/18/12	Warm, no rain	8kg	3.3kg	4.7kg	Fighting, not eating much.
005/19/12	Warm, no rain	5kg	3.5kg	1.5kg	Fighting, not eating much.
005/20/12	Cloudy, no rain	5kg	3.7kg	1.2kg	Fighting, not eating much.
005/21/12	Warm, no rain	6kg	5.2kg	800g	Fighting, not eating much.
005/22/12	Cloudy, no rain	5kg	3.7kg	2.3kg	Fighting, not eating much.
005/23/12	Hot, sunny day	6kg	5.7kg	300g	Started settling down
005/24/12	Warm, no rain	6kg	5.3kg	700g	Started settling down
2005/25/12	Warm, no rain	6kg	4.7kg	1.3kg	Started settling down
005/26/12	Warm, no rain	6kg	5.3kg	700g	Started settling down
005/27/12	Warm, no rain	6kg	5.1kg	900g	Eating well
005/28/12	Warm, no rain	6kg	5.1kg	900g	Eating well
005/29/12	Cloudy, no rain	5kg	2.5kg	2.5kg	Not fighting
005/30/12	Drizzle	5kg	4kg	1kg	Not fighting
005/31/12	Rain	5kg		Wet left overs	
1/1/2006	Rain	5kg		Wet left overs	
2/1/2006	Rain	4Kg		Wet left overs	
3/1/2006	Rain	4kg		Wet left overs	
4/1/2006	Rain	4kg		Wet left overs	
5/1/2006	Rain	4kg		Wet left overs	
6/1/2006	Rain	4kg		Wet left overs	
7/1/2006	Warm, no rain	5kg	4.6kg	400g	No fighting
8/1/2006	Warm, no rain	5kg	4.6kg	400g	No fighting
9/1/2006	Rain	5kg		Wet left overs	
10/1/2006	Rain	5kg		Wet left overs	
11/1/2006	Rain	6kg		Wet left overs	
12/1/2006	Rain	6kg		Wet left overs	
06/13/01	Rain	6kg		Wet left overs	
06/14/01	Warm, no rain	7kg	6.7kg	300g	Eating well

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06/15/01	Warm, no rain	7kg	6.8kg	200g	Eating well
06/16/01	Warm, no rain	8kg	7.8kg	200g	Eating well
06/17/01	Hot, no rain	9kg	8.7kg	300g	Eating well
06/18/01	Sunny day	9kg	8.3kg	700g	Eating well
2006/19/01	Sunny day,	9kg	7kg	2kg	Eating well
2006/20/01	Drizzle	7kg		Wet left overs	
2006/21/01	Cloudy, no rain	9kg	8kg	1kg	Eating well
2006/22/01	Cloudy, no rain	8kg	7.8kg	200g	Eating well
2006/23/01	Cloudy, no rain	8kg	7.9kg	100g	Eating well
2006/24/01	Rain	6kg		Wet left overs	
2006/25/01	Warm, no rain	9kg	8.8kg	200g	Eating well
2006/26/01	Warm, no rain	9kg	5kg	4kg	
2006/27/01	Cloudy, no rain	7kg		Wet left overs	
2006/28/01	Rain	5kg		Wet left overs	
2006/29/01	Rain	5kg		Wet left overs	
2006/30/01	Rain	5kg		Wet left overs	
2006/31/01	Rain	5kg		Wet left overs	
1/2/2006	Rain	5kg		Wet left overs	
2/2/2006	Warm, no rain	7kg	8.9kg	100g	
3/2/2006	Warm, no rain	9kg	7.64kg	1.36kg	
4/2/2006	Rain	8kg		Wet left overs	
5/2/2006	Rain	6kg		Wet left overs	
6/2/2006	Rain	6kg		Wet left overs	
7/2/2006	Rain	6kg		Wet left overs	
8/2/2006	Rain	6kg		Wet left over	
9/2/2006	Rain	6kg		Wet left over	
10/2/2006	Warm, no rain	9kg	7.14kg	1.86kg	
11/2/2006	Rain	7kg		Wet left overs	
12/2/2006	Rain	6kg		Wet left overs	
06/13/02	Rain	7kg		Wet left overs	
06/14/02	Rain	7kg		Wet left overs	
06/14/02	Rain	7kg		Wet left overs	
06/15/02	Rain	7kg		Wet left overs	
06/16/02	Rain	7kg		Wet left overs	
06/17/02	Cloudy, no rain	9kg	5.83kg	3.17kg	
06/18/02	Cloudy, no rain	9kg	7.8kg	1.2kg	
06/19/02	Cloudy, no rain	9kg	5.36kg	3.64kg	
06/20/02	Cloudy, no rain	9kg	7.23kg	1.77kg	
06/21/02	Cloudy, no rain	9kg	6.84kg	2.16kg	
06/22/02	Cloudy, no rain	9kg	6.62kg	2.38kg	

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			Group 2 (17% CP)		
DAY	**TEMP**	**FEED/DAY**	**FEEDCONSUMED/DAY**	**LEFT-OVER/DAY**	**OBSERVATION/REMAR**
9/12/2005	Hot sunny day	8kg	8kg	Wet left overs	Birds eating well
10/12/2005	Hot sunny day	9kg	9kg	Wet left overs	Birds eating well
11/12/2005	Hot sunny day	10kg	10kg	Wet left overs	Birds eating well
12/12/2005	Warm, no rain	11kg	11kg	Wet left overs	Birds eating well
2005/13/12	Warm, no rain	14kg	14kg	Wet left overs	Birds eating well
2005/14/12	Warm, no rain	16kg	16kg	Wet left overs	Birds eating well
2005/15/12	Warm, no rain	16kg	16kg	Wet left overs	Birds eating well
2005/16/12	Warm, no rain	18kg	14.3kg	3.7kg	Intake decreased
2005/17/12	Hot sunny day	15kg		Wet left overs	
2005/18/12	Warm, no rain	14kg	10.7kg	3.3kg	Intake decreased
2005/19/12	Warm, no rain	13kg	11kg	2kg	Intake decreased
2005/20/12	Cloudy, no rain	14kg	13.8kg	200g	Eating well
2005/21/12	Warm, no rain	16kg	15.8kg	200g	Eating well
2005/22/12	Cloudy, no rain	15kg	14.7kg	300g	Eating well
2005/23/12	Hot, sunny day	15kg	13.7kg	1.3kg	Intake decreased
2005/24/12	Warm, no rain	16kg	14.5kg	1.5kg	Intake decreased
2005/25/12	Warm, no rain	16kg	13.3kg	2.7kg	Intake decreased
2005/26/12	Warm, no rain	15kg	11.6kg	3.4kg	Intake decreased
2005/27/12	Warm, no rain	15kg	14kg	1kg	Intake decreased
2005/28/12	Warm, no rain	15kg	13.5kg	1.5kg	Intake decreased
2005/29/12	Cloudy, no rain	14kg	13.1kg	900g	Eating well
2005/30/12	Drizzle	14kg	10kg	4kg	Intake decreased
2005/31/12	Rain	8kg		Wet left overs	
1/1/2006	Rain	9kg		Wet left overs	
2/1/2006	Rain	9kg		Wet left overs	
3/1/2006	Rain	9kg		Wet left overs	
4/1/2006	Rain	8kg		Wet left overs	
5/1/2006	Rain	8kg		Wet left overs	
6/1/2006	Rain	8kg		Wet left overs	
7/1/2006	Warm, no rain	6kg	5.2kg	800g	Eating well
8/1/2006	Warm, no rain	6kg	5.5kg	500g	Eating well
9/1/2006	Rain	6kg		Wet left overs	
10/1/2006	Rain	6kg		Wet left overs	
11/1/2006	Rain	6kg		Wet left overs	
12/1/2006	Rain	6kg		Wet left overs	
2006/13/01	Rain	5kg		Wet left overs	
2006/14/01	Warm, no rain	10kg	9.8kg	200g	Eating well
2006/15/01	Warm, no rain	10kg	9.4kg	600g	Eating well
2006/16/01	Warm, no rain	9kg	7.5kg	1.5kg	Eating well
2006/17/01	Hot, no rain	9kg	8.7kg	300g	Eating well

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2006/18/01	Sunny day	9kg	8.5kg	500g	Eating well
2006/19/01	Sunny day,	9kg	7.7kg	1.3kg	Eating well
2006/20/01	Drizzle	8kg		Wet left overs	
2006/21/01	Cloudy, no rain	8kg	7.4kg	600g	Eating well
2006/22/01	Cloudy, no rain	8kg	7.5kg	500g	Eating well
2006/23/01	Cloudy, no rain	8kg	7.4kg	600g	Eating well
2006/24/01	Rain	6kg		Wet left overs	
2006/25/01	Warm, no rain	7kg	6kg	1kg	
2006/26/01	Warm, no rain	8kg	5.7kg	2.3kg	
2006/27/01	Rain	8kg		Wet left overs	
2006/28/01	Rain	6kg		Wet left overs	
2006/29/01	Rain	6kg		Wet left overs	
2006/30/01	Rain	6kg		Wet left overs	
2006/31/01	Rain	7kg		Wet left overs	
1/2/2006	Rain	7kg		Wet left overs	
2/2/2006	Warm, no rain	10kg		120g	
3/2/2006	Warm, no rain	12kg	10.62kg	1.38kg	
4/2/2006	Rain	8kg		Wet left overs	
5/2/2006	Rain	8kg		Wet left overs	
6/2/2006	Rain	8kg		Wet left overs	
7/2/2006	Rain	8kg		Wet left overs	
8/2/2006	Rain	8kg		Wet left overs	
9/2/2006	Rain	8kg		Wet left overs	
10/2/2006	Warm, no rain	10kg	7.02kg	2.98kg	
11/2/2006	Rain	9kg		Wet left overs	
12/2/2006	Rain	7kg		Wet left overs	
2006/13/02	Rain	6kg		Wet left overs	
2006/14/02	Rain	6kg		Wet left overs	
2006/14/02	Rain	8kg		Wet left overs	
2006/15/02	Rain	8kg		Wet left overs	
2006/16/02	Rain	8kg		Wet left overs	
2006/17/02	Cloudy, no rain	9kg	5.81kg	3.19kg	
2006/18/02	Cloudy, no rain	9kg	8kg	1kg	
2006/19/02	Cloudy, no rain	9kg	5.35kg	3.65kg	
2006/20/02	Cloudy, no rain	9kg	5.51kg	3.49kg	
2006/21/02	Cloudy, no rain	9kg	7.33kg	1.67kg	
2006/22/02	Cloudy, no rain	9kg	5.83kg	3.17kg	

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			Group 3 (14% CP)		
DAY	**TEMP**	**FEED/DAY**	**FEEDCONSUMED/DAY**	**LEFT-OVER/DAY**	**OBSERVATION/REMARKS**
9/12/2005	Hot sunny day	8kg	8kg	Wet left overs	Birds eating well
10/12/2005	Hot sunny day	9kg	9kg	Wet left overs	Feed increased but ate all
11/12/2005	Hot sunny day	10kg	10kg	Wet left overs	Feed increased but ate all
12/12/2005	Warm, no rain	11kg	11kg	Wet left overs	Feed increased but ate all
2005/13/12	Warm, no rain	14kg	14kg	Wet left overs	Feed increased but ate all
2005/14/12	Warm, no rain	16kg	16kg	Wet left overs	Feed increased but ate all
2005/15/12	Warm, no rain	16kg	14kg	2.0kg	Intake decreased
2005/16/12	Warm, no rain	15kg	13.1kg	1.9kg	Intake decreased
2005/17/12	Hot sunny day	14kg	12.8kg	1.2kg	Eating well
2005/18/12	Warm, no rain	14kg	12.8kg	1.2kg	Eating well
2005/19/12	Warm, no rain	14kg	13.2kg	800g	Eating well
2005/20/12	Cloudy, no rain	14kg	12kg	2kg	Eating well
2005/21/12	Warm, no rain	13kg	12.1kg	900g	Eating well
2005/22/12	Cloudy, no rain	14kg	13.8kg	200g	Eating well
2005/23/12	Hot, sunny day	14kg	12kg	2kg	Eating well
2005/24/12	Warm, no rain	14kg	12kg	2kg	Eating well
2005/25/12	Warm, no rain	13kg	12.5kg	500g	Eating well
2005/26/12	Warm, no rain	14kg	11.2kg	2.8kg	Eating well
2005/27/12	Warm, no rain	14kg	12.8kg	1.2kg	Eating well
2005/28/12	Warm, no rain	14kg	13.4kg	600g	Eating well
2005/29/12	Cloudy, no rain	12kg	8kg	4kg	Feeding intake reduced
2005/30/12	Drizzle	12kg	9kg	3kg	Feeding intake reduced
2005/31/12	Rain	10kg		Wet left overs	
1/1/2006	Rain	10kg		Wet left overs	
2/1/2006	Rain	9kg		Wet left overs	
3/1/2006	Rain	9kg		Wet left overs	
4/1/2006	Rain	9kg		Wet left overs	
5/1/2006	Rain	9kg		Wet left overs	
6/1/2006	Rain	9kg		Wet left overs	
7/1/2006	Warm, no rain	6kg		2.2kg	Feeding intake reduced
8/1/2006	Warm, no rain	6kg	2kg	4.kg	Feeding intake reduced
9/1/2006	Rain	6kg		Wet left overs	
10/1/2006	Rain	6kg		Wet left overs	
11/1/2006	Rain	5kg		Wet left overs	
12/1/2006	Rain	6kg		Wet left overs	
2006/13/01	Rain	5kg		Wet left overs	
2006/14/01	Warm, no rain	10kg		200g	
2006/15/01	Warm, no rain	10kg	8.9kg	1.1kg	Eating well
2006/16/01	Warm, no rain	9kg	7.8kg	1.2kg	Eating well
2006/17/01	Hot, no rain	8kg	6kg	2kg	Feeding intake reduced
2006/18/01	Sunny day	8kg	6.6kg	1.4kg	Feeding intake reduced

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2006/19/01	Sunny day,	8kg	4.3kg	3.7kg	Feeding intake reduced
2006/20/01	Drizzle	8kg		Wet left overs	
2006/21/01	Cloudy, no rain	7kg	5.4kg	1.6kg	Eating well
2006/22/01	Cloudy, no rain	7kg	6.6kg	400g	Eating well
2006/23/01	Cloudy, no rain	7kg	6.8kg	200g	Eating well
2006/24/01	Rain	4kg		Wet left overs	
2006/25/01	Warm, no rain	5kg	4kg	1kg	
2006/26/01	Warm, no rain	6kg	4.4kg	1.6kg	
2006/27/01	Rain	6kg		Wet left overs	
2006/28/01	Rain	5kg		Wet left overs	
2006/29/01	Rain	5kg		Wet left overs	
2006/30/01	Rain	4kg		Wet left overs	
2006/31/01	Rain	5kg		Wet left overs	
1/2/2006	Rain	5kg		Wet left overs	
2/2/2006	Warm, no rain	7kg	6.9kg	0.1kg	
3/2/2006	Warm, no rain	9kg	7.62kg	1.38kg	
4/2/2006	Rain	6kg		Wet left overs	
5/2/2006	Rain	6kg		Wet left overs	
6/2/2006	Rain	6kg		Wet left overs	
7/2/2006	Rain	6kg		Wet left overs	
G8/2/2006	Rain	6kg		Wet left overs	
9/2/2006	Rain	5kg		Wet left overs	
10/2/2006	Warm, no rain	8kg	7.45kg	0.55kg	
11/2/2006	Rain	8kg		Wet left overs	
12/2/2006	Rain	5kg		Wet left overs	
2006/13/02	Rain	5kg		Wet left overs	
2006/14/02	Rain	5kg		Wet left overs	
2006/14/02	Rain	6kg		Wet left overs	
2006/15/02	Rain	6kg		Wet left overs	
2006/16/02	Rain	5kg		Wet left overs	
2006/17/02	Cloudy, no rain	7kg	3.48kg	3.52kg	
2006/18/02	Cloudy, no rain	7kg	5.6kg	1.4kg	
2006/19/02	Cloudy, no rain	7kg	4.02kg	2.98kg	
2006/20/02	Cloudy, no rain	7kg	4.08kg	2.92kg	
2006/21/02	Cloudy, no rain	7kg	6.5kg	0.50kg	
2006/22/02	Cloudy, no rain	7kg	6.35kg	0.65kg	

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APPENDIX 4(B)

Summary of consumption per day per group for the 3 groups

PERIOD		**GROUP 1: 20% CP**	**GROUP 2: 17% CP**	**GROUP 3: 14% CP**
09- to 29-Dec-05	CONSUMPTION PER DAY/GROUP	HIGHEST: 8kg/day LOWEST: 2.5kg/day CONDITION: warm/no rain	HIGHEST: 16kg/day LOWEST: 8kg/day CONDITION: Warm/no rain	HIGHEST: 16kg/day LOWEST: 8kg/day CONDITION: warm/no rain
30-Dec-05 to 13-Jan-06	CONSUMPTION PER DAY/GROUP	HIGHEST: 6kg/day LOWEST: 4 kg/day CONDITION: Rainy	HIGHEST: 10kg/day LOWEST: 5.2kg/day CONDITION: Rainy	HIGHEST: 9kg/day LOWEST: 2kg/day CONDITION: Rainy
14-J to 26-Jan-06	CONSUMPTION PER DAY/GROUP	HIGHEST: 8.8kg/day LOWEST: 5kg/day CONDITION: Cloudy/no rain	HIGHEST: 9.8kg/day LOWEST: 5.7kg/day CONDITION: warm/no rain	HIGHEST: 8.8kg/day LOWEST: 4kg/day CONDITION: Warm/no rain
27-Jan-06 to 16-Feb-06	CONSUMPTION PER DAY/GROUP	HIGHEST: 7.64kg/day LOWEST: 5kg/day CONDITION: Rainy	HIGHEST: 10.62kg/day LOWEST: 6kg/day CONDITION: Rainy	HIGHEST: 7.62kg/day LOWEST: 4kg/day CONDITION: Rainy
17-Feb- to 22-feb-06	CONSUMPTION PER DAY/GROUP	HIGHEST: 7.8kg/day LOWEST: 5.36kg/day CONDITION: Cloudy/no rain	HIGHEST: 8.0kg/day LOWEST: 5.35kg/day CONDITION: Cloudy/no rain	HIGHEST: 6.5kg/day LOWEST: 3.48kg/day CONDITION: Cloudy/no rain

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